THE RADIOLOGY OF BONES AND JOINTS

By

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FOURTH EDITION

With 615 Illustrations



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To my wife AMY
and to the memory of her sister
my former secretary
ELSIE C STEWART
and of my friends
NAUGHTON DUNN
LEONARD MACKEY
and
JOHN ROBERTSON

teachers in the Birmingham Medical School who with their help and advice did so much to make the writing of this book possible

PREFACE ... EDITION

So multitudinous are all the ... been produced by the X ray departments of the world that one w... t it possible within a few years to complete a book which would have em... he possible changes in bones and joints. Yet the many additional facts gleaned from my own departments and the world's literature of every branch of medical science which have rapidly accumulated since the previous edition have entailed very considerable revision and additions. It is such experience which brings home the truth of the sentiments expressed by Roentgen in his rectorial address at Würtzburg in 1894: "The scientist must consider the possibility, which usually amounts to a certainty, that his work will be superseded by others within a relatively short time, that his methods will be improved upon and that the new results will be more accurate and the memory of his life and work will gradually disappear." (*O. Glasser.*)

To assist in demonstrating the various lesions recorded more than 200 other radiographs have been chosen. In some cases serial radiographs from normality to restitution or disintegration have been used to show the changes in appearances throughout, for these time-tables of changes have an important bearing on the diagnosis and treatment.

When Roentgen's discovery of X rays was announced in the public press in January 1896 the notices stressed the importance of the discovery as a means of examination which would save the patients pain. The author believes this should be the essential motive of every radiographic investigation, for the wider our knowledge of radiographic appearances, particularly of bones and joints, the less need there should be to resort to biopsy or other painful preliminary investigations. Unfortunately there is an urge to explore what appears to be any unusual or spectacular radiographic lesion, often without carefully considering the risks to the patient or the poverty of the contribution which this will make for his benefit. The contribution of evidence of malignancy so obtained at a stage when the clinical and radiographic evidence appears to indicate simplicity of the lesion will not be acted upon by the surgeon, whose experience has taught him that histological findings are not infallible and possible of considerable variation in interpretation by different expert pathologists; we shall have a long way to travel if we continue to be satisfied with the insecurity of amputation as a means of cure of malignant disease.

The author's aversion to biopsy is not of mushroom growth. He began his pathology at the age of 18 years when he was appointed in 1900 to do the photomicrography in the Pathological and Bacteriological Departments of the University of Birmingham where he learnt that the best photographs were obtained when he selected, prepared, mounted and stained his own material. For some nine years he did this with human and animal tissues—the latter he derived from the city abattoir when he was working under the direction of the late Sir John Robertson. It is only the painful lessons learnt of the fallibility of histological interpretation of pathological tissues which have quenched the urge such a training brings.

The author regards himself fortunate that in spite of the dispersal and disintegrat... of material through two world wars he has been able to preserve his records and co... with most of the patients whose radiographic history he desired to follow. He ... to express his gratitude to the contributions of the great team named in the ... for without their aid many features and contributions would not have b...

they often provided the basic facts from which to start. To my many clinical and radiological colleagues who have supplied me with radiographs and data of interesting cases particularly F G Allan, Richard Connell, T S Donovan, P Franklyn Garratt Hardman A. M Hendry F H. Kemp J B Leather Charles McDonough, F P Montgomery W W Rentoul F Wilson Stuart Prof Waldenström, may I express the hope that the contents of the book will be considered a worthy return. Many thanks are due to Mr A. M. Hendry my assistant at the University Dr Roger Britt, and his wife for their time and patience given to reading and correcting the proofs.

Lastly my gratitude is extended to the members of the radiographic teams at all the hospitals I serve for their continued loyalty and help throughout many years In particular I would mention Sister Hill and her staff, her deputy Mrs Binns (Royal Cripples Hospital) Sister Benedict (The Warwickshire Orthopædic Hospital), Sister Chapman and Mr Philips (Birmingham Accident Hospital) Sister Le Gallais (Queen Elizabeth Hospital), Mr William Smith (Anti-tuberculosis Centre and Military Hospital)

Many thanks are due to my wife and my secretary Miss Margaret Huckerby for their help with the index and additions

To assist the student the author has personally compiled the index, including in it the numbers of the illustrations and the features they show

For permission to use extracts from my papers in the *British Journal of Surgery* the *Practitioner* the *Lancet*, *Medical Press* I wish to thank the Editors The Editor of the *British Institute of Radiology* I have to thank also for some of the blocks used.

The return to such excellent quality paper and the marshalling of the text is due to the unstinted help of Mr J Rivers his staff and the printers, to whom I extend my most grateful thanks.

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PREFACE TO THE FIRST EDITION

The advent of radiography has considerably extended our knowledge of the growth, development and structure of the bones and joints in health and disease. To-day the science with its advanced technique graphically provides delicate details of osseous changes that may clinch a diagnosis when clinical signs and symptoms are indefinite.

The detail and technique of radiography not only demand a specialist in execution and interpretation but also compel the radiologist to take an active clinical part in scientific medical research, differential diagnosis, treatment and prognosis, unless he is content to adopt the position of a qualified technician.

There is urgent need to stress the value of periodic radiographic examination of the changes occurring in normal and irregular growth, in the inception and progress of systemic and localised disease and before, during and after the exhibition of various forms of treatment. The fact must be appreciated that the lapse of a few weeks may supply the clinician with striking radiographic evidence though the first radiographic report may have been of little or no positive value. Again, while various pathological conditions present similar clinical signs, fortunately their respective radiographic appearances are distinctly characteristic and afford invaluable evidence in diagnosis. Apart from setting forth concisely an account of the bone changes seen in health and disease, it is one of the chief purposes of this book to indicate the significance of the radiographical findings and further to present briefly the recent advances already recognised by X ray departments and radiographic journals but not yet adequately appreciated by general text books, all arguments directly responsible for this publication.

As the compass of the book precludes the possibility of illustrating every condition of bone lesion, typical illustrations have been selected and references to monographs and articles published in the chief radiological journals of the world containing further illustrations will be found by the inquirer for special details of any particular subject. This list includes many of the important contributions to radiological literature during the last twelve years, each article containing a long bibliography beyond the scope of the average reader.

The Royal Cripples Hospital, Birmingham, and the Warwickshire Orthopædic Hospital dealing with congenital, developmental, traumatic and pathological bone conditions producing deformity, the Birmingham War Hospitals, and subsequently the Birmingham Pensions Hospitals concerned with bone injuries sustained during the war and the resultant disabilities, the Queen's Hospital, Birmingham, affording examples of systemic and localised diseases producing bone changes, the City of Birmingham Infant Welfare Centres demonstrating the bone diseases of infancy, and the Department of Anatomy of the University of Birmingham yielding additional facilities for the post mortem study of bone abnormalities, are the various institutions to which I am indebted for the experience presented.

I thank my colleagues and the staffs of the X ray departments of these hospitals for their helpful co-operation and advice, in particular Mr Naughton Dunn, who throughout the past eighteen years has supplied me with the clinical and operative details and subsequent results of a large number of the patients whose radiographic findings are herein recorded. I am indebted to Dr Robert Lockhart, Professor of Anatomy of the University of Birmingham, and A. M Hendry, Assistant Orthopædic Surgeon, Shropshire

Orthopædic Hospital, Oswestry for reading through the manuscript and making many essential suggestions in its arrangement Sister Manaton and Nurse Thomas of the Royal Cripples Hospital for their help in preparing the illustrations. I am grateful to Sister Chapman, of the Queen's Hospital, Sister Benedict, of the Warwickshire Orthopædic Hospital, and Sister Garvie of the Carnegie Infant Welfare Centre for their assistance with the radiography and histories of the patients. I have to thank numerous personal friends who have submitted interesting cases and my secretary Miss Elsie Stewart for eager and meticulous perseverance in the preparation of the manuscript for the press

For the use of the four radiographs from which Figs 30 218 00 and 190 are made I am indebted to Drs R. M. Beath and F P Montgomery G B Dixon, S L. Mucklow and A. E. Payne

The quality of the reproductions and the general setting of the book testify to the skill and care which Messrs J & A. Churchill their artists and printers have expended in the publication, and I would particularly thank Mr John Rivers for the courtesy and help he has given.

JAMES F BRAILSFORD

BIRMINGHAM.

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FIG. 1 Antero-posterior radiograph of full-term fœtus.

PART I

REGIONAL RADIOGRAPHY

CHAPTER I

THE SKELETON AT BIRTH

RADIOGRAPHIC examination of the full time fœtus at birth commonly shows the bones in the stage of ossification shown in Fig 1 As a rule no ossified nuclei for epiphyses are present except one for the epiphysis of the lower end of the femur and sometimes a smaller one for the head of the tibia and the head of the humerus

The ossification of the diaphyses appears to be uniform throughout all the bones. The middle third of the shaft shows a compact cortex, which gradually thins out as it approaches the proximal and distal thirds, so that the expanded extremities appear to be composed throughout of a fine cancellous reticulum of uniform density so fine that it may be detected on an unscreened film only the grain of intensifying screens obliterating it

The nutrient foramen can be made out in the large long bones. In the femur it is seen as a foramen or distally directed breach of the cortex about 1 mm in diameter just proximal to the mid point of the shaft and in the humerus a similar structure just distal to the mid point and directed towards the elbow A smaller foramen can sometimes be detected in the radius, ulna and tibia at the junction of the middle and upper thirds. The extremities of the diaphyses are clearly defined and regular in outline As the cartilage of the epiphyses does not show at the joints there appear to be wide gaps between the extremities of the long bones, the widest gap being at the knee joint, followed by the wrist, hip shoulder and elbow joints. Nuclei for the os calcis and astragalus are large and beginning to show evidence of their shape. A small nucleus for the cuboid may also be present it may be double with the dorsal element smaller than the plantar In the wrist a smaller nucleus for the os magnum may be the only indication of ossification of the carpus The nucleus for the body of the hyoid and the pair for the greater horns are also visible, while an elongated oblong ossicle for the manubrium and four separate quadrate nuclei of gradually diminishing size represent the sternum at birth An ossified nucleus for the coracoid process may be recognisable

THE SKULL

Lateral Radiograph. The striking feature of the skull is the relatively large cranium and smaller facial parts, which at this stage form but one-eighth of the bulk of the head whereas in the adult, the two regions are of about the same size In the lateral radiograph the vault extends in a uniform line from the base of the nose to the occiput. This line is broken at the anterior and posterior fontanelles and at the junction of the supra-occipital and condylar elements of the occipital bone The basilar segment and the petro-mastoid appear as a denser and a somewhat quadrangular mass in the middle third of which the outline of the cochlea the vestibule, the semicircular canals and tympanic antrum may be distinguished for they are little less in size than in the adult the outlines of the tympanic antrum and cochlea are partly obscured by the dense surrounding bone Early mastoid cell development may be detected in a small percentage

(Welin [3]) The sphenoid, which at this stage is almost as dense as the petro-mastoid is separated from the outline of the latter by a slight gap. It exhibits on its superior surface the sella turcica with relatively dense anterior and posterior clinoid processes. The roofs of the orbits are shown as slight upwardly directed convex outlines extending from the sphenoid to the base of the frontal bone. Little or no detail of the bony structure within the outline of the vault can be distinguished. In the mandible and maxillae inverted V-shaped denticles can be recognised with their bases directed towards the cyst like cavities of the dental sacs, which at this stage occupy about two-thirds of the depth of the mandible The maxillary antrum is about a $\frac{1}{4}$ inch in diameter The ununited nasal bone is shown projecting forward like an avulsed bony spicule. With a focus-film distance of 36 inches the maximum antero-posterior dimension of the outline of the bony skull is 5 inches while the depth from vertex to occiput is 4 inches. The soft tissue of the scalp at this stage appears to be about $\frac{1}{4}$ inch in thickness It has been estimated that the diameters of the head increase in the later weeks of intrauterine life at the rate of $\frac{1}{10}$ inch per week

The Antero-posterior Radiograph. The antero-posterior radiograph even more emphasises the diminutive size of the facial bones and the relatively large orbits. The outline of the vault is continuous except for the breach at the sagittal suture. The two sides of the mandible have not united The nasal septum is shown, but only a faint indication of the maxillary antrum can be seen. This is the only visible representative of the accessory nasal sinuses. The maximum transverse diameter (bi parietal) of the bony skull is 4 inches with a focus-film distance of 30 inches.

THE SPINE

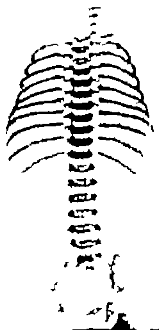


Fig. 2. Antero posterior radiograph of spine of full-term foetus.

The Antero-posterior Radiograph. On the antero-posterior radiograph the spinal column shows the greatest transverse diameters in the cervical and upper sacral segments and the least in the lumbar and lower sacral segments. The distances between the opacities of the pedicles indicate the size of the spinal canal. This is shown to be wider in the cervical and lumbo-sacral areas—to accommodate the origins of the brachial and lumbo-sacral plexuses—gradually diminishing in size through the lumbar and dorsal segments, the minimum width being in the second dorsal vertebra. The vertebral bodies ovoid in shape with a slight notch in the superior and inferior surfaces in the mid line in the dorsal segments show a progressive increase in size from the third cervical to the fourth lumbar from which they diminish to the last of the sacral vertebrae On account of the increased width of the spinal canal and the lesser size of the vertebral bodies in the cervical area, the opacities of the pedicles appear to occupy a plane lateral to the vertebral body so that there appears to be a gap between their nearest borders almost equal to the width of the vertebral body but in the dorsal and lumbar area larger pedicles form an almost parallel line of opacities behind and on a plane with the lateral borders of the bodies. With the diminution of the size of the sacral bodies the pedicles again appear to be on a plane lateral to the bodies. The centre for the odontoid has not ossified so that it appears to have been cut

off The dorsal vertebral bodies show an appearance of two small holes one on either side of the mid line; these are not so clearly defined in the cervical area, but in the lumbar area they are larger show some lateral branching and appear to fuse in the mid line giving a somewhat Y-shaped transparency The appearances are made by vascular channels The transverse processes of the dorsal vertebræ are well formed and show greater development than in any other part of the spine the lumbar transverse processes are merely represented by rounded tubercles. The laminæ in the dorso-lumbar area are closely approximated posteriorly in the mid line, but not fused above and below this area they show a gradual increase in the medial space (unossified cartilage) which separates them. The convex posterior extremities of the ribs are on a plane slightly medial to the lateral borders of the dorsal transverse processes; their bodies show a gradual expansion of the anterior third the anterior extremities of which are slightly concave

The sacrum is represented by five separate bodies with associated pairs of ossicles for the upper four neural arches and two pairs of triangular shaped ossicles for the upper elements of the lateral mass. An ossific nucleus of the upper segment of the coccyx may be visible. The three elements of the innominate bone are ununited In the middle of the lower half of the ilium a stellate vascular pattern can be made out (see Fig 2).

The Lateral Radiograph. The striking feature of the lateral radiograph in contrast with that of the adult spine is the relatively small size of the vertebral bodies compared to that of the elements of the neural arch. The line of the vertebral bodies presents two primary curvatures, a general backward curvature from the cervical to the lumbo-sacral junction, at which point the direction of the curvature is fairly abruptly changed, the line of the sacral bodies being directed backwards but presenting throughout a slight anterior concavity The lower lumbar bodies appear almost circular in shape with an ill-defined band of relative radio-transparency in the middle third running from front to back. As the column is ascended a clear-cut notch appears in the middle of the anterior surface and a smaller but less well-defined, notch can be seen in the posterior surface, which is most marked in the dorsal area, where the bodies appear to be bobbin-shaped, the notches leaving but the middle third apparently ossified A small gap appears to separate the bodies from the quadrate pedicles In the lumbar area the distally directed processes which will bear the inferior articular surface are large and in striking contrast to the diminutive elements of the superior processes.

General. It will be seen, therefore that each vertebra is represented by a body and two postero-lateral bony elements one on each side forming the neural arch These three elements are united by cartilage and the spinous processes are still cartilaginous (see Fig 3)

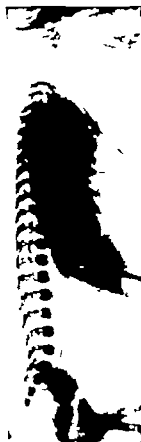


FIG 3. Lateral radiograph of spine ribs sternum and pelvis of full-term fœtus

In the dorso-lumbar area an increase in the curvature may be present and radiographs will show it is associated with a body of diminutive size and perhaps some irregularity in shape The abnormal curvature (see Fig 839) and changes associated

with achondroplasia and the severer degrees of the osseous and chondrous dystrophies may be recognisable.

Premature Infants. As we should expect from Table I, premature infants show a diminished ossification corresponding with their lessened maturity The most helpful radiographic features indicating maturity are the number of visible osseous nuclei *i.e* epiphyses for the head of the humerus, head of tibia, distal end of femur and nuclei for the coracoid os magnum cuboid astragalus and os calcis, the distal third and fourth segments of sternum and a nucleus for the body and one for each of the greater horns of the hyoid, and the degree of ossification of the vertebral column and skull. In the healthy full time fœtus all these nuclei should be visible and the vertebral column and skull exhibit the degree of ossification described in a previous chapter With a diminution of the maturity the radiograph fails to reveal the nuclei for the coracoid the head of the humerus, the os magnum, the hyoid and the distal fourth segment of the sternum. With still less maturity the radiograph may not show the nucleus for the head of the tibia or for the cuboid while in a fœtus less than eight months no nucleus for the distal end of the femur can be detected, for this does not appear until the ninth month It is however generally held that an infant exhibiting ossification of the distal end of the femur is mature

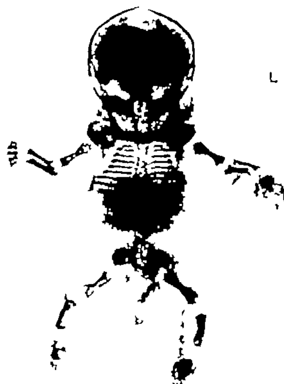


Fig 4 Achondroplasiac fœtus showing the characteristic short stumpy bones of the extremities.

Prematurity is frequently associated with syphilis and severe degrees of the osseous and chondrous dystrophies. The radiographic features of these are often characteristic. Fig 4 shows the essential features of fœtal achondroplasia the squat scapulæ and ilii the short stumpy long bones with their splayed-out ends, which though irregular in outline do not show the blurred effect of defective ossification and osteoid formation seen in chondro-osteo-dystrophy Note also the indication that ossification of the vertebral bodies begins in the lower dorsal area and spreads up and down the column just as we have noticed at a later date in the ossification of the neural arches The defective ossification of the fœtal skeleton in osteogenesis imperfecta is illustrated in Figs. 14 A and B

Fœtus in Utero. In the radiographs of the pregnant woman near full term it is possible to show in the fœtus *in utero* many of the el… including the nuclei for the distal end of the femur the head of the tibia and t… s and astragalus Owing to the bulk of the maternal b… the lie of the fœ… not be possible to show all nuclei and the detail of t… icture will not defined but the demon

stration of any of the nuclei we have noted as characteristic of the full time fœtus and a measurement of the fœtal head by the simple method described by *Reece* will permit of a good estimate of the maturity and a careful examination of the skeleton for the features previously described will give a good index of the normality of the fœtus. In the case of a multiple pregnancy it is as important to examine each fœtal skeleton with equal care. Definite disparity in the sizes of the fœtuses is an important feature to note. The smaller fœtus may be dead or exhibit disturbances of development or pathological changes such as are described in the following chapter. If subsequent radiographs show a normal increase in development of the larger fœtus with no apparent development of the smaller the suspicion of its death is confirmed. The rate of development of the female skeleton is usually in advance of the male and using this feature some authorities have suggested that a comparative study of the fœtal skeleton *in utero* will permit the recognition of the sex of the fœtus. Unfortunately this sexual difference in skeletal development rates does not become marked until after birth. The author has radiographically examined the skeleton of mixed twins and in some cases the ossification of the male fœtal skeleton was in advance of the female twin.

Major defects in the development of the fœtal skeleton and evidence of certain osseous dystrophies may be recognised (see Figs 4 8, 9 10 11 12, 13 14)

Intra-uterine Ossification of the Fœtus. Radiography of the pregnant woman will



Fig 5 Radiograph of fœtus during the ninth month showing general flexion

not reveal any signs of pregnancy until the fœtal skeleton is sufficiently ossified to possess a density greater than that of the maternal soft tissues (see Fig 14A).

The following table indicates the age of the fœtus at which osseous nuclei have been demonstrated in the bones by the anatomist —

TABLE I

Skull		Frontal bone	6th—7th week.
		Parietal	8th week
		Occipital	6th—8th week.
		Sphenoid	8th—10th week
		Maxilla and mandible	6th week
		Temporal bone	2nd—5th month
		Zygoma	8th—10th week
		Nasal bone	8th week.
Hyoid		Body and greater horns	9th week
Spine	Cervical	Arch	7th week.
		Body	15th week.
	Thoracic	Arch and body	10th week.
	Lumbar	Arch and body	15th week.
	Sacrum	Arch and body	20th week
	Coccyx		1st year to puberty
Ribs			6th week
Sternum		Manubrium	5th month.
		1st segment	6th month
		2nd segment	7th month.
		3rd segment	8th month.
		4th segment	9th month.
LOWER EXTREMITY			
Pelvis		Ilium	3rd month.
		Ischium	4th month.
		Pubis	5th month.
Femur Tibia and fibula			7th week
Os calcis			6th month
Astragalus			8th month.
Cuboid			9th month.
Metatarsals			9th week
Phalanges	Distal		3rd month.
	Proximal		4th month
	Middle		6th month.
UPPER EXTREMITY			
Clavicle			5th week.
Scapula			
Humerus			
Radius and ulna			
Os magnum			
Metacarpals			
Phalanges			

From an examination of the above table it will be seen that at the end of the second month of pregnancy elements of the skull spine and limb bones will have begun to ossify and therefore we might expect to get evidence of this on the radiograph By projecting the uterine shadow free from the pelvic bones and the shadows of rectal and colonic contents, the early ossification can be shown on good quality radiographs *Jungman* illustrated a series of cases in which he demonstrated ossification in the living fœtus within the maternal pelvis at the eighth or ninth week of pregnancy Failure to show radiographic detail of the fœtal skeleton at this early stage should not be regarded as conclusive evidence that pregnancy does not exist Fœtal movements during exposure may be the cause Apart from the fact that the detail will be missed except with the best radiographs it must be realised that delay in ossification may be caused by a number of conditions. In the condition of **Fœtal Osteogenesis Imperfecta** (*Vrolik*) radiographs of the pregnant mother near full term may show the outline of the enlarged uterus but little or no detail of the fœtal skeleton. In one case which came under the author's notice the only parts of the fœtal skeleton recognisable were the petro-mastoids and on more careful examination a thin outline of the vertex. The latter had been missed and the petro-mastoids had been reported as calcified glands (see Figs 14 A and B) Usually by the fifth month the fœtal skeleton is sufficiently ossified to produce unmistakable radiographic evidence Death of the fœtus may occur at any age After ossification of the skull has proceeded so far that it shows as an almost continuous outline death is indicated by overlapping of the cranial bones (**Spalding's sign**). This overlapping of course must be distinguished from the overlapping of the cranial bones which is associated with the moulding accompanying the latter stages of pregnancy It was well seen in the case of a **Fœtus Papyraceous** or **Compressus** illustrated in Fig 6 In this case the doctor told me that the patient gave a history of a fall during the early months of pregnancy Though radiographs of the dead fœtus (sharp in detail because of immobility) may not show any recognisable features when taken with the pregnant mother lying down particularly in breech presentation with the mother standing it will be appreciated that the body of the dead fœtus has lost the tone of the living and consequently it adopts the position due to gravity and adjacent structures *i.e.*, it collapses In case of doubt the evidence of failure of development, or the production of the above signs, may be sought by comparative further radiography at a late date



FIG 6 Radiograph of normal fœtus with fœtus papyraceous (ninth month).

Fœtus Papyraceous Fœtus papyraceous is usually found in twin pregnancy

Death of the fœtus probably results from damage to the fœtal circulation by trauma or pressure of the other fœtus or from maternal illness. The twins develop from one ovum, each having its own amniotic sac and death occurs during the fourth–fifth month, sometimes, as in the case illustrated, without producing any recognisable signs. At the time of the death of the fœtus the size of the uterus may suggest twin pregnancy but after this has occurred its amniotic fluid is absorbed, the fœtus is gradually compressed and desiccated so that at full term no evidence of twin pregnancy except from the radiograph, may be detected (see Fig 6). Its recognition is important, as the dead fœtus may obstruct and delay labour or be retained and give rise to serious post partum complications. Occasionally it is born first or comes away with the placenta. Serial radiographs after the death will show the progressive compression of the dead fœtus and a continuous development of the live fœtus. When death of the fœtus in a single pregnancy occurs maceration readily leads to disintegration and radiographic evidence of this will be seen in the overlapping of the bones of the fœtal skull and unnatural disposition of the other elements of the fœtal skeleton. Maceration had occurred in 10 of 18 syphilitic fœti out of a total of 838 cases of stillbirth investigated by *Gillespie*. Other observers have recorded a still higher figure.

Lithopædion. A lithopædion is the desiccated remains of a fœtus in an extra uterine pregnancy. In the past it has been a relatively rare finding but with the more frequent use of radiography a larger number will be discovered. *Mathieu* records that up to 1937 but 229 had been recorded in the literature. The extra uterine pregnancy may be associated with a normal intrauterine fœtus and the latter may go to term leaving the former unrecognised for as long as 40 years, when it may be discovered accidentally by radiography or at autopsy. Radiographs will show the lithopædion within the shadow of the brim of the pelvis. Its appearance will depend upon the age of the fœtus and the length of time which has elapsed since its death and the degree of compression to which it has been subjected. Within the first year it may have similar appearances to those of a fœtus papyraceous, particularly if it was associated with an intrauterine fœtus. If it has not been subjected to great pressure from a full term intrauterine fœtus, its skull outlines will be preserved even though the remainder of the skeleton of the fœtus is crowded together and compressed. Radiographs of such a fœtus of 4 or 5 months in the maternal pelvis will show the typical characters of the fœtal skeleton but compression may be so severe that recognition of its nature will not be so ready, particularly if much calcium has been deposited in the tissues surrounding it. The radiograph published by *Mathieu* illustrates the features of such a lithopædion which had been present in the abdomen for 25 years but the radiograph published by *Schubert* of the lithopædion of a 4 months-old fœtus, which had been dead but a few months, clearly shows the outlines of the fœtal skull and the skeleton of the compressed trunk and limbs.

POSITION AND APPEARANCE OF THE FŒTUS IN UTERO

One of the most helpful features of the radiography of the pregnant woman is the demonstration of the position and presentation of the fœtus or a number of fœti, factors which cannot always be determined with certainty by the clinical examination. The normal fœtus is shown to be generally flexed in most vertex presentations. Except at the lumbo-sacral juncture from which place the curvature alters because the sacrum is directed backwards, the fœtal spine shows a general forward concavity. In breech and other less common presentations the legs, head or other members may become extended, features which should be indicated to the obstetrician. For indications of Fœtal Death, see p. 7

Placenta Previa An ante-natal knowledge of the position of the placenta has i above interest to the obstetrician Unfortunately the majority of the radiographs pregnant woman taken with ordinary technique fail to indicate its site Shadows th to be due to it have been shown by *Chassar Moir* to be produced by pools of amniotl Many attempts have been made to show the placental site by using different techn The injection of opaque fluids or air into the amniotic sac has not been very suc and they are not devoid of danger When radiographs show that a normal sized h presenting part of the fœtus is high above the pelvic brim of normal dimension displaced, the question of placenta previa is raised The exclusion of rectal, bow



Fig 7A. Lateral radiograph of pregnant woman showing fœtal head box and nterior to pel ic brim. Placenta previa



Fig 7B. Postero-anterior radiograph of

bladder contents as the cause by the use of enemata and catheterisation, would l to consider the possibility of cervical fibroids, meningocele, ovarian cyst or th rare hydatid or other cyst or tumour in the differential diagnosis The visua of the bladder by the injection of abrodil into it will indicate the thickness of th between the presenting part and the bladder wall, but it will not indicate the na the space occupying tissue For the demonstration of placenta previa we need graphs whose high quality is indicated by sharp definition of soft tissue outlines, gr of half tones, and absence of the fogging effects of scattered radiation Such graphs can be obtained with modern units of high output activating a fine focu which permits of such rapid exposures less than one second, that no movement patient or fœtus occurs during the exposure Any movement during the e would vitiate the results.

Using thick graduated filters near to the tube *F H Kemp* and his assistant have succeeded in showing, in a high percentage of routine radiographs, the pos

the placenta, and the outlines of the uterus In those cases in which the placenta site obviously enlarged and expanded by the associated cord and fluid accumulations, is not indicated, its location can be deduced from the absence of any opacity of reasonable size from all other parts of the uterine wall. The persistence of the shadow with relative dimensions at the site has been noted after version and the localisation of the placenta has been confirmed at Cæsarean section The quality of the radiographs produced in this way is very high and cannot fail to provide the obstetrician with valuable knowledge of the placental site long before any symptoms have aroused suspicion. Even for operative purposes a knowledge of the placental site can be of great value. Such radiographic possibilities must obviate the necessity of more injurious digital and other examinations, and permit of guarded expectant treatment, which might permit the fœtus to arrive at such maturity that subsequent surgery is achieved without fœtal death—at present commonly recorded as 50 per cent. in cases of placenta previa.

Signs of Fœtal Injury With the increase in automobile accidents the possibility of injury to the fœtus is increased and radiographs may show evidence of the damage Compressed fracture of the fœtal skull within the brim of the pelvis is the most readily recognised In one case seen by the author the fœtal head was shown to be completely crushed in this position Damage less readily detected soon after the accident may become apparent later by the radiographic signs of fœtal death or by the deposition of calcium in hæmatomata at the site of a fracture



Fig 8A. Radiograph showing double-headed fœtus in utero Not that the skulls are in the same relative plane with the spine parallel and similarly directed except in the cervical and upper dorsal areas, also the abnormal conjoint ribs.

Hydramnios. In all cases of hydramnios radiography of the *pregnant woman is advisable* At best it is associated with multiple fœti the number and position of which will be shown, but it is often associated with abnormalities and defects of development. By the *examination of 338 stillbirths Gillespie* found that malformations *were the cause of death in about* one-third of the cases

Careful examination of the details of the fœtal skeleton should be made. *If two or more fœti are* present the positions and structures will give an indication whether they are entirely separate from one another Fœti of the same size are usually normally developed, but, as *in the example shown*, actual bony union may exist between them (see Figs 8, A and B) If one fœtus is smaller than the other the smaller will generally be the abnormal fœtus If attached to its twin it will usually show some serious defect in development If unattached it may be assumed to

be dead a suspicion which can be confirmed by radiographs taken at a later date showing the features of fœtus papyraceous. Gross abnormalities of the single fœtus incompatible with life such as acrania (see Fig 9) anencephalus cephalodymus



Fig 8B. Radiograph of fœtus shown in 8A The mother was 31 years of age and this was her first pregnancy Clinically diagnosed as probable twins. Four weeks before full term she had an antepartum hæmorrhage and a Cæsarian section was done that night. The monster lived for about an hour Both heads breathed and they cried independently and died simultaneously

cephalothoracopagus (see Fig 10) hydrocephalus, meningocele myelocele and exomphalus can be detected as well as fusions of the lower extremities.

The Anencephalic Fœtus. The striking feature of this fœtus is the absence of any sign of ossification of the bones of the cranium or any indication of the bulk of its contents. It is in the latter respect that the appearances differ from the hydrocephalic fœtus The diminutive size of the facial bones referred to in the normal fœtus will be apparent. The fœtal spine is surmounted by what in the radiograph of the fœtus *in utero* appears to be an irregularly flattened ossified mass. More careful inspection of good lateral radiographs of the fœtus will generally reveal some of the details of the petro-mastoid even with the semicircular canals the basiocciput, the mandible and maxilla with their denticles, the orbits and other prominent features of the facial bones. In the antero-posterior radiograph of the intrauterine fœtus, the details of the face and base of the skull are not so readily recognised The position of the fœtal cephalic extremity particularly when presenting in the pelvis will be such that the lack of the bulk of the normal cephalic mass is at once apparent. Though this



Fig. 9 Acrania. Full-term foetus. Note epiphyses at knee joints.



Fig. 10 Cephalothoracopagus.

defect in the development of the cranium and its contents may be seen with little or no further maldevelopment of the spine or other elements of the skeleton it is common to find it associated with other defects in the spine of a severe degree

Complete Myelocele Complete myelocele is not unusual with anencephaly It has been illustrated by the author [11] It is associated with irregular development of the vertebral bodies and ribs In this condition the fœtal spine is unduly dwarfed by the fusion and cramping together of diminutive cervical and even also the upper dorsal vertebral elements, and it presents abnormal curvatures the most common of which is found in the lumbar area as a hump containing the elements of six or eight vertebral bodies arranged in a regular posterior convexity No spinous processes can be seen in the region of the hump On the antero-posterior radiograph the enlarged size of the lumbar bodies is striking and the pedicles, instead of lying on a plane with the lateral borders of the bodies and directed backwards with the laminæ almost meeting in the mid line as in the normal, are lateral to the bodies and directed laterally leaving a wide gap between the laminæ which measures almost double the width of the normal fœtal spine It may be possible to recognise multiple hemivertebræ and deformities of the



FIG 11 Localised myelocele of lumbar spine of intra-uterine fœtus (note characteristic curvature)

ribs the heads of which being perforated sometimes resemble the heads of needles. In some cases antero-posterior or lateral angulations of the spine may be recognised in association with large quadrangular lumbar bodies immediately below

Localised Myelocele. I[31] have previously indicated that when there is a localised myelocele the fœtus presents the characteristic hump which can be recognised in the fœtus *in utero* (see Fig 11) The vertebral elements contained in the hump present the features

described in a previous paragraph, *i.e.*, the vertebral bodies appear superficial and enlarged, the pedicles are lateral to, and directed away from, the bodies, leaving a wide gap between the extremities of the ossifying laminæ.



FIG. 12A. Apert's deformity of skull.



FIG. 12B. Defective ossification of parietal bones with some degree of hydrocephalus.

Localised Spina Bifida and Spinal Defects of a less serious nature may be clearly indicated on the radiograph of the fœtus but as these are compatible with life they have not the same serious significance

The Hydrocephalic Fœtus. Distinct from the anencephalic fœtus the bulk of the cranium and *its contents is indicated by the* position of the fœtal head relative to the

surrounding structures, though little sign of ossification of the cranium may be apparent In most cases, however some ossification of the cranial bones will be seen The most usual is the occipital bone and after it the floor of the anterior fossa and the inferior part of the frontal bones.

The diminutive size of the facial bones, which present normal features, is in striking contrast with the enlarged cranium The condition is often associated with myelocele

The mistake has been made of diagnosing hydrocephalus from the normal fœtal head the outline of which has been enlarged by the projection of its shadow at the increased distance from the radiographic film when the pregnant woman was radiographed lying supine on the film; the degree of ossification of the cranial bones and the comparative sizes of cranial and facial bones should prevent the error being made

Lacuna Skull. In this condition the ossification of the fœtal skull is defective and may be associated with hydrocephalus. It is possible in good lateral radiographs of the intrauterine fœtal head to see the irregular ossification of the skull particularly in the frontal and occipital areas. It has a characteristic appearance is not a very uncommon lesion and is not incompatible with life (see Fig 13)



Fig 13 Lacuna skull of full-term fœtus

Meningocele. Radiographs of the intrauterine fœtus may fail to show even a large meningocele In some cases it may be suspected from the position of the fœtal head or spine In others it is indicated by an interruption of the normal cranial curvature which may present a binovular appearance. In some cases the edges of the hole in the cranium are turned back by the protruding mass and this may be recognisable.

Exomphalus. In this condition there is a marked Scoliosis of the Fœtal Spine which produces an unusual shortening of the fœtal trunk, a feature which will be very noticeable in breech presentations, for the fœtal head near term will not be above the plane of the second or third maternal lumbar vertebra. The elements of the fœtal skeleton apart from this are normal

Hydrops Fœtalis (Erythroblastosis Neonatorum). In this condition the fœtus appears to be pushed against the wall of the uterus and the main contents of the uterus appear as a soft tissue mass. Considerable displacement of the fœtus may occur when the pregnancy is associated with a large ovarian cyst in this condition the fœtus is more frequently depressed by a soft tissue mass above. *C T Javert* has described as typical a Buddha or frog like position of the fœtus which he ascribes to the large liver and ascites. He publishes a radiograph showing a halo-like effect around the fœtal head which he says is caused by œdema of the scalp

Congenital Defects of Extremities. Absence of or gross deformities of the extremities of the intrauterine fœtus due to defective development of fusion may be recognised. Foreshortening of the limbs due to an unusual position or projection of the fœtus sometimes arouses the suspicion of developmental defects a suspicion which may be dispersed by further projections

The most important of these defects are the sympodia, which may either exhibit a tapering of the trunk without lower extremities (Sirenomyelia) or the latter may be more or less fused together (Uromelia or Symmelia).

DYSPLASIAS AND DYSTROPHIES OF THE FŒTAL SKELETON

Abnormalities of development usually described under the terms dysplasia or dystrophy though the use of the latter term is probably best restricted to those with changes which are known to be associated with deficient or faulty nutrition, show all degrees of severity Some so severe as to be incompatible with life, others less severe *permitting life to continue into infancy adolescence or even late adult life (see p 517)*

Reference has been made to the fact that the fœtal skeleton in severe Osteogenesis Imperfecta, even near term, may not be recognisable in the best radiographs. If, *therefore, the outline of the enlarged uterus is shown with, perhaps, the ill-defined opacities of* the petro-mastoids (which have been mistaken for calcified glands) but little or no other detail, this condition should be suspected Such fœti are usually stillborn The condition *was first described by Vrolik The following is a description of such a case:—*

A radiograph of the pregnant woman two days before delivery showed an enlarged uterus with two ill-defined opacities, which were thought to be calcified glands, and the abdominal mass a large ovarian cyst. More careful examination of these radiographs revealed that the opacities showed the characters of the petro-mastoids and with this identification it was possible



Fig 14A. Radiograph of pregnant woman with fœtus at full-term. The arrows indicate the two opacities due to petro-mastoids. An outline of the cranium is faintly indicated in the frontal and occipital areas. Case of fœtal osteogenesis imperfecta (Vrolik) (see Fig 14B).

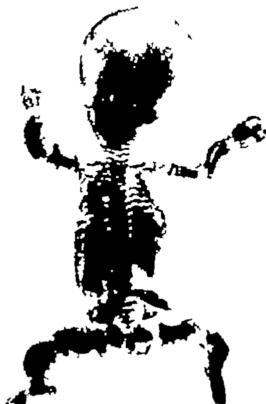


Fig. 14B. Osteogenesis imperfecta fœtalis.

to recognise a very faint outline of the fœtal skull. The fœtus was in its ninth month and was the first pregnancy. The maternal pelvis revealed areas of cancellous absorption which aroused the suspicion of osteitis fibrosa of the hyper-parathyroid type.

Radiographs of the still-born fœtus showed :—

Skull. Very little ossification of the vault. Denticles in the upper and lower jaws. Fracture-like appearances in the mandible.

Spine. Bodies ossified but smaller and flatter than normal, having well-defined regular outlines but little or no sign of internal cancellous structure. The laminæ were adjacent at the dorso-lumbar junction but separated above and below this.

Ribs. Crowded together, thicker than normal and of almost uniform calibre, possessing a creased ribbon appearance due to multiple fractures.

Clavicles. Granular in appearance, thicker and showing no differentiation into compact and cancellous tissue.

Humeri. Short, stumpy, of almost uniform thickness throughout, granular in appearance with multiple fractures resembling creases.

Radius and Ulna. Not so stumpy as the humeri but bent and exhibiting multiple fractures.

Metacarpals and Phalanges. Similar to the radius.

Pelvis. Well-defined ossicles for the sacrum, but having the general granular appearances of the other elements.

Femora. Similar to the humeri. Epiphysis of the lower end was well defined.

Tibia. Similar to the femur.

Tarsus. Nuclei for os calcis and astragalus.

Metatarsals and Phalanges. Similar to the hand (see Fig. 14, A and B).

Albers-Schönberg's Disease, etc. In contrast with the former, fœtal bones showing this dystrophy may be recognised by their unusual increased density. Only a few such cases have been described.

Other dystrophies and defects such as **Achondroplasia, Cranio-cleido-dysostosis, Cranio-facial Dystrophy of Apert** (see Fig. 12A) may be recognised in the radiographs of the intra-uterine fœtus.

An unusual development of the skeleton is shown in Fig. 15. The uniform marked expansions of the extremities of all the long bones, the femora resembling dumb-bells, with increased density of their extremities, the dense flat vertebral bodies separated by deep disc spaces, the irregular spiky dense borders of the os calcis and astragalus bear no resemblance to the other dysplasias. Unfortunately the infant survived but a few days and no further investigation was possible.

Unusual position of the fœtal head may be due to **hygroma** or **massive cervical tumours**, but their nature will not be revealed until the infant is born.



Fig. 15.—Very unusual ossification of fœtal skeleton. Note the expanded extremities of the long bones and the added density of the growing surfaces. The infant survived only 5 days.

CALCINOSIS CHONDRODYSTROPHIA CALCIFICANS CONGENITA

In the newly born infant multiple dense calcium deposits may be detected in the soft tissues—particularly in the neighbourhood of cartilage. The extent and distribution of the deposits vary. In some cases the deposits may be so small as to be overlooked

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FIG 14A. Radiograph of pregnant woman with fœtus at full-term. The arrows indicate the two opacities due to petro-mastoids. An outline of the cranium is faintly indicated in the front l and occipital areas. Case of fœtal osteogenesis imperfecta (Vrolik) (see Fig 14B).



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in others producing spectacular dense deposits, sometimes, as in *Borovsky-Ardent's* case (which showed a high phosphatase), appearing to fill the capsules of several of the larger joints, such as the knee, hip ankle, shoulder or elbow joints. Deposits may be found in the region of the larynx, ribs, or vertebræ and in the subcutaneous and intra muscular planes In the region of the distal carpus and tarsus, multiple small dense deposits may be seen distinct from the ossific nuclei which appear to develop normally The bones may not show any change but in some cases elevation of the periosteum with new bone accretions have been shown in the long bones. Stunting of limbs and some of the features of achondroplasia have been recorded Several infants in the same family may show the condition, as in the cases described by *Raap*, one of whom died the father exhibited congenital defects in the phalanges In the majority of cases the calcium deposits were gradually absorbed and by the age of 8 years no sign remained. The etiology is unknown, but in some cases there is a definite syphilitic history as in *Tisdall* and *Erb's* case, which also had a congenital heart lesion. *A Bloxham* and *R A. Johnson* report the clinical and radiographic features of a baby at birth which showed superficial plaques of calcium and deposits in the neighbourhood of the joints and the spine Diet aimed at correcting the defective calcium metabolism resulted in the absorption of much of the calcium but even at 7 months deposits were present in the ankle, wrist and knee areas. At 11 months congenital cataract appeared in both eyes. This condition is apparently distinct from those cases which appear to be associated with deficient thyroid, for in the latter the ossific nuclei for the epiphyses and small bones appear to be represented by small calcium deposits and when true ossification begins the epiphyses are laid down in multiple nuclei In the 8-months-old female cretinoid infant recorded by *Conradi* who first drew attention to the condition, stippling of the lower femoral epiphyses distal tibia and fibula epiphyses and tarsus was found. In the case of the premature infant boy with the signs of cretinism published by *Blatt, Zeldes* and *Goodfriend* the calcific islands were scattered in the region of the epiphyses without conforming to the usual pattern of the epiphyses (femora, humeri) or centres of ossification (os calcis and astragalus) and later fused into an irregular mass. The infant died at 3 months *Siegert* has published an illustrated account of a patient whose radiographs showed multiple ossific nuclei for all the epiphyses of the hands and feet. The patient was a boy born of apparently healthy parents, though the mother had suffered in her youth from lymphatic disturbances which were evident in all her children. The boy had suffered from eczema, recurrent sore throat rhinobronchitis and hyperplasia of the tonsils from the time he was one year of age. He was somewhat backward in development and at 2½ years he ceased to grow Myxœdema was diagnosed and 0·01 gram of iodothyrin per day was prescribed. This medication was interrupted by various illnesses and in the fourth year it was given up entirely and not resumed until the eighth year when he was again given 0·01 gram per day He came under observation in a condition of complete athyreosis when he was 9 years of age. His mental and physical development was that of a child of 2 years. On 0·03 gram of iodothyrin a day he was completely changed in 7 days. From July 1930 to the summer of 1932 medication was regular but then it was omitted on account of severe sore throat and there was another relapse which was promptly checked by treatment in August 1932. Radiographs of the hands on July 30th, 1930 when he was 9 years of age, showed multiple epiphyseal nuclei for the proximal phalanges, radius and two carpal bones only but 4 months later (November 27th, 1930) multiple nuclei for the metacarpals had appeared.

Siegert called the condition Osteogenesis Chondrodysplastica and regards it as an anomaly of ossification leading to arrested development due to hormonal disturbances and to disease processes.

The radiographic appearances of the epiphyses bear some resemblance to the epiphyses in the condition of chondro-osteo-dystrophy

INJURIES

Birth Injuries. Intrauterine fractures at birth will usually show massive callus. The bones most commonly broken during obstetric manipulations are the humerus and femur. The humerus is fractured in its middle third, the femur at the junction of its middle and upper thirds. The fracture of the former is usually transverse, while the latter is oblique. At the end of 7 days radiographs will show a cloudy deposit of calcium in the hæmatoma around the fracture; in 2 weeks the calcium deposit is about at its maximum and has arrived at its greatest density; during the third week the calcium is organised and takes on the radiographic characters of bone and by the fourth week a sound plumber's wiped joint appearance is given. If the alignment of the fragments is kept good at the end of 2–3 months little or no evidence of the fracture will be detectable. Shortening due to overlap of the fragments produces changes which can be seen for as long as 2 years, but the shortening is apparently corrected during the growth. Bilateral femoral capital epiphyseal separation may occur from trauma.

Obstetric Shoulder. Injuries to the shoulder of the infant during its passage through the birth canal are not infrequent. They may be associated with injury to the brachial plexus, to the skeletal tissues, or to both; consequently in some cases with paralysis there may not be any sign of injury to the shoulder joint, while in others fractures or displacements may not be accompanied by any paralysis. Of the lesions which can be shown by radiography fracture of the clavicle is the most obvious, particularly during the second week of life for then massive callus will be seen at the site of the fracture. Injuries to the shoulder joint may not be readily detected immediately after birth, but, as with the clavicle, the damage becomes evident with the passage of time. Damage to the upper end of the humeral diaphysis is shown by calcium deposits in a subperiosteal hæmatoma, but damage to the epiphysis is not revealed until ossification has commenced. The injury sustained at the shoulder joint may be likened to that seen in cases of congenital dislocation of the hip for the humeral epiphysis has been displaced and the growth cartilage has sustained damage. As a result of this the joint space appears to be wider than on the normal side, the ossification of the epiphysis is delayed and its growth impaired so that it is smaller than the normal side. Antero-posterior and cranio-caudal radiographs, with the arm outstretched and the cassette placed in the axilla, will show the smaller epiphysis to be displaced laterally and backward from the glenoid fossa, while with the more severe trauma the growth of the scapula may be impaired and it then appears to be elevated, when contrasted with the uninjured scapula. As a result of the displacement and interference with growth the deformity may persist through life and serial radiographs of the area, particularly in childhood, will reveal unusual moulding of the damaged epiphysis and diaphysis, delay in ossification of the tuberosities and poor development of the glenoid fossa.

A good account of these lesions with illustrations has been published by *Scaglietti*

CONGENITAL CRANIAL OSTEOPOROSIS

(Congenital Cranio-tabes or osteomalacia)

This condition, a clinical feature, is found in 10-35 per cent. of infants in the parietal bone more commonly the right, along the line of the sagittal suture, in infants under weight or who possess facial asymmetry or signs of delay in ossification, born as first children by vertex presentation in the winter or late autumn. It does occur in apparently healthy children of normal weight and in infants who do not fall into the above groups.

Its ætiology is unknown—it has been the subject of very considerable controversy. Some regarding it as a physiological response to pressure of the head *against the pelvis* or of the growing brain on the cranium, others as the result of such factors of light, food or other deficiencies of the mother in the late months of pregnancy others as a manifestation of syphilis or rickets. It is confused by some with the true cranio-tabes *of rickets* which becomes more apparent 3 months later and shows a seasonal incidence. In some cases true cranio-tabes may follow but usually the congenital form disappears during the first *few* weeks of life, *i.e.*, before the age of the former

It is determined by gentle palpation, consequently its recognition may be dependent upon the experience and skill of the examiner It is not associated with any definite radiographic evidence.

A good account is given by *O Reiss* and *E Bodes*

FACTORS INFLUENCING SUBSEQUENT OSSIFICATION

By consulting the many text-books which state the age at which the various ossific nuclei appear and unite, considerable differences in the ages stated will be noted. This is probably due to the fact that the method of determining the presence of an ossific nucleus is not the same in all cases while in others the figures are based on but a small number of examinations.

Attempts have been made, notably by *Todd* and *Flory* to arrive at a skeletal age by comparing the degree of ossification of the epiphyses of the bones of the hand and the ossification of the carpal and tarsal nuclei. They may be conveniently used in the majority of cases, but in others you may find the epiphyses are in considerable advance of the carpal or tarsal epiphyses, or *vice versa* *Robinow* suggests that the round bone and the epiphyseal skeletal ages should both be used. Thyroid deficiency is closely related to delay in ossification which some authorities think may express itself more in either epiphyseal or round bone growth. Figs. 16 *A*, *B* and *C*, are of a girl cretin, *A* at the age of 5 years 2 months when she weighed 2 st. 8 lbs. and measured 2 feet 10 inches—her skeletal age judged on the *Todd* standard was then 6 months. She had had no thyroid. *B* is 3 months later during which time she had received thyroid Her skeletal age has not changed, she had lost 5 lbs, but gained 2 inches in height *C* is 16 months later She had received thyroid for 19 months. At the age of 6 years 9 months *her skeletal age was* 7 *years 3 months*. *Her height 3 feet 8 inches and her* weight 3 st. 0½ lbs. in other words, on thyroid her ossification had advanced 6 years 9 months in 1 year 7 months. The ossification of the bones is still not normal, the cortical and cancellous tissues are deficient. *Some workers record effects of thyroid at a shorter* interval. In cretins the bone ends are well defined—the epiphyseal plate may appear to be denser Retardation of the linear growth of the long bones, which is a feature in cretinism, *can be measured from serial radiographs of the radius and ulna.*

Delay in ossification is also seen in diabetes mellitus. *I A Bogan* investigated by radiographs the hands of 95 diabetic boys and 74 girls. He found that, generally speaking the longer the duration of the diabetes, the greater the retardation All boys with more than 10 years duration and all girls with diabetes of more than 9 years duration showed retardation. An inconstant increase in the degree of retardation is noted with an increase in the duration of the diabetes and the age of the patient. Twenty per cent. showed retardation of osseous growth of more than 2 years and 13·6 per cent. had retardation of more than 3 years—the incidence being greater in boys than girls. Anomalies of development were observed in one fourth of the diabetics In the earlier years in 15 per cent of the boys and 13·6 per cent of the girls the skeletal growth is accelerated



A



B.

Fig. 10. Radiograph of a girl at the age 5 years 2 months.

A. Skeleton age 0 months. Weight 2 st. 8 lbs. Height 2 feet 10 inches. No thyroid medication.

B. Age 5 years 3 months. Skeleton age 0 months. Weight 2 st. 8 lbs. Height 3 feet. Thyroid medication for 3 months.

C. Age 6 years 9 months. Skeleton age 7 years 3 months. Weight 3 st. 6½ lbs. Height 3 feet 8 inches. Thyroid medication 1 year 7 months.

Thus skeletally she aged 0 years 9 months in 1 year 7 months.



C.

Bogan uses a radiographic illustration of the hand of a 4-year-old boy with diabetes of 18 months duration, it shows an osseous age of 4 years 9 months judged in *Todd's* standard and 3 years according to *Flory's*. The greatest amount of retardation observed in a male was 7 years. This amount occurred in a man of 20 years with diabetes of 12 years duration. The greatest amount of retardation seen in a female was 9 years. This amount occurred in a 25 year-old woman with diabetes of 18 years duration.

Retardation of growth has also been recorded in cases of underfeeding, certain gastro-intestinal disorders, severe illness, deficiency of minerals in milk.



FIG. 17. Lumbar spina bifida. Hypoplasia of bones of left lower extremity.

Neural and neuro-vascular defects also appear to delay ossification, thus a child of 4 months with spina bifida showed on one side a normal femoral capital epiphysis as large as a pea but on the other no sign of ossification. Hypoplasia of the whole limb may be seen as in Fig. 17. In the unusual osseous dystrophy which I[88] recorded none of the proximal carpal nuclei had appeared at the age of 10 (see Fig. 21) and no epiphyses for the terminal phalanges had appeared at 18 years yet at 10 many of the other epiphyses had fused and at 18 years the femoral and tibial epiphyses had fused.

Failure of one or more epiphyses to fuse may be a familial characteristic, as may also premature fusion as in the cases described by the author.[44]

Pryor has shown that while in the newly born the advance in ossification of the female skeleton in front of the male may be one of days only, the times of fusion of the epiphyses differ by years.

Many other factors appear to influence ossification including climate race fresh air food light—particularly ultra violet—and exercise Ossification is advanced in certain conditions such as pubertas precox—the activity of the gonads having a profound influence on the rate of ossification—thus girls of 11–12 with sexual precocity may show fusion of all the epiphyses—but it is retarded in disorders of certain endocrine glands such as the pituitary and thyroid.

In hypogonadism or eunuchism there is definite delay in the fusion of the epiphyses with the diaphyses

While some authorities consider that illness during childhood affects the rate of ossification this is denied by others It is possible that the balance of endocrine activity may have been affected in some cases and not in others. Localised disease of the bones may produce advancement or retardation of ossification of that part

Two or three bony nuclei may appear for individual epiphyses, as, for example the phalanges, metacarpals, metatarsals, olecranon, acromion patella, etc., and these must not be mistaken for fractures.

The majority of epiphyses and other ossific centres are built up from regular nuclei, but sometimes they are irregular in form. Such irregularities are most frequently seen in the femoral epiphyses, the tarsal scaphoid cuboid, and the vertebral bodies. The explanation for their appearance apart from hypothyroidism or osseous dystrophy has not been determined.

Additional epiphyses may develop, as, for example, epiphyses at both ends of the phalanges metatarsals and metacarpals—these frequently indicate serious bone dystrophies and during the course of one's work amongst children the discovery of these extra epiphyses has suggested further radiographs of the skeleton which have revealed unsuspected dystrophies. In certain cases isolated epiphyses appear to remain ununited to the main bone long after fusion of the other epiphyses has taken place The cause for this is unknown—trauma, which might be suggested is usually the cause of premature fusion The shadows of these ununited epiphyses in the radiographs of patients who have sustained injury to the part frequently cause misinterpretation In a number of cases exhibiting isolated epiphyses, sometimes bilateral, which have failed to fuse other members of the family have been found to have the same defect

The articles by *Adair* and *Scammon Buonsanti Cohn Davies* and *Parsons Engelbach P Lewin Paterson Pryor Sawtell Schin*., should be consulted by the student requiring detailed particulars.

In osteogenesis imperfecta ossification is often advanced thus the femoral capital epiphyses may show an ossific nucleus in each the first week of life and the vertebral epiphyses may be ossified as early as the 4th year

THE UPPER EXTREMITY

CHAPTER II

THE HAND AND WRIST

General. Radiographs of the hand may furnish the observer with much information as to the age of the patient, the presence of familial or congenital deformities, chondrous and osseous dystrophies, foreign bodies, localised bone or joint disease or tumour formation, and evidence of specific general skeletal pathology.

Careful attention to the *stage of ossification, the regularity of epiphyses, extra epiphyses*, the appearances of the compact and cancellous structure and of the growing extremities of the diaphyses will often direct attention to developmental irregularities or pathological changes.

The best radiographs of the hand are obtained without the use of intensifying screens—that is to say, the films should be exposed in simple paper wrappers. This ensures close contact between the hand and the film and secures detail of the finest cancellous structure of the bones. Contrast in the detail of the bone can be obtained by using a relatively soft radiation. Films taken with intensifying screens will perhaps give greater contrast but at the expense of detail and half tones. With young children it is often advisable to limit the time of exposure to $\frac{1}{10}$th of a second.

As a general rule it is advisable to expose both hands on the one film, so that the two sides can be compared. The usual technique is to place the patient's palm firmly against the film—if only the thenar eminence and the tips of the fingers rest against the film, foreshortening of the phalanges and metacarpals will occur, the amount depending upon the angulation of the individual bone to the film. Such foreshortening has given rise to errors in interpretation. Lateral radiographs with the film against the inner side of the hand or against the side of any particular finger, or semilateral radiographs *with the fingers bent to a varying degree so that their shadows will not be* superimposed, may give additional help in diagnosis.

OSSIFICATION

Phalanges. Ossification of the bones of the hands commences in the diaphyses of the phalanges and metacarpals about the eighth to tenth week of intrauterine life. At *birth the diaphyses of the phalanges and metacarpals have assumed a distinctive shape*; no ossification, except in a very few cases, can be detected in the epiphyses, the carpal bones may be represented by a nucleus of the os magnum.

The diaphyses of the terminal phalanges at this stage are dumb-bell shaped and show a fine reticulate structure with no evidence of differentiation or compact bone. The middle phalangeal diaphyses *show a similar internal structure, but have a rounded* distal extremity and a flattened slightly convex proximal extremity, which is slightly wider than the distal. There is a slight concavity of the lateral borders of the phalanges. The lateral borders show a finer reticulation which at the junction of the middle and distal thirds extends almost across the entire width of the bones. The middle phalanges are about 1½ times as long as the distal. A small hole is often seen in the terminal and middle phalanges about the junction of the middle and distal thirds. This is the nutrient *foramen*. It appears to be unduly prominent in cases of skin tuberculides and leprosy.

The proximal phalanges are nearly 1½ times as long as the middle phalanges and

have a similar shape but the proximal extremity appears flatter. The lateral borders are rather straighter than those of the middle phalanges. They show a greater differentiation between the cortex and the medulla, the finer and denser reticulation of the cortex having a convex inner border widest at the junction of the middle and distal thirds and tapering to both extremities.

The metacarpals have slightly concave lateral borders, and a flattened and somewhat convex distal extremity of a little greater width. The first metacarpal is shorter with a definite concave inner border and a flattened proximal extremity. The cortex is slightly denser but narrower than that of the proximal phalanges. The reticulation of the medulla is rather more open than that of the phalanges.

The appearance of ossification in the epiphyses of the phalanges and metacarpals and of the nuclei for the carpal bones is usually to be detected earlier in the female though instances of earlier ossification in the male are occasionally met with. The radiographs of early ossification of the nuclei for the epiphyses show small flattened ovoid opacities lying opposite but free from the proximal ends of the phalanges. The first epiphysis to show signs of ossification is the epiphysis of the proximal phalanx of the index finger; this occurs generally in the second year of age (though one has met with instances in which ossification generally has been advanced so that nuclei for all the epiphyses were shown on the radiograph during the first year of life). Ossification of the nuclei for the epiphyses of the proximal phalanges of the middle and ring finger follows soon after and, by the time the child is 2½ years of age, all the epiphyses of the proximal phalanges can be shown. The nuclei of the epiphyses of the middle phalanges then begin to appear in the same order, all being visible on radiographs of children about the age of 3 years; the epiphyses of the terminal phalanges can usually be detected at the age of 3½ years.

The epiphysis of the base of the terminal phalanx of the thumb is sometimes shown to commence as two separate nuclei which fuse during development. Its epiphysis usually appears before that of the proximal phalanx and is the first to fuse—in the female this may be seen at the age of 12 years.

On the radiograph of a hand showing all the epiphyses of the phalanges, the epiphyses of the terminal phalanges appear as biconcave discs about the same width as the base of the diaphyses of the terminal phalanges; the epiphyses of the middle phalanges tend to assume a plano-convex shaped disc—the convex surface being opposed to the slightly concave distal extremity of the proximal phalanx. The epiphyses of the proximal phalanges are flattened discs having a slightly convex distal surface and a slightly concave proximal surface—the epiphyses of the middle and ring finger being slightly thicker on the outer side. Before fusion with the diaphyses takes place the epiphyses of the terminal and middle phalanges have been moulded to articulate with the concave distal extremities of the phalanges and they are therefore thicker in the middle than at the periphery. The epiphyses of the proximal phalanges are by this time definitely concave on their proximal articular surface.

Variations in the ossification of the bones of the hand, their cause and frequency appears to have given rise to differences of opinion. They concern for the most part the development of the so-called **Pseudo-epiphyses** and the **True Supernumerary Epiphyses**, the latter being regarded as developments from a separate centre of ossification, the former as a bony extension from the diaphysis into its cartilaginous extremity.

Of 1,000 apparently healthy normal children (examined by the author) 80 showed abnormal ossification of the metacarpal bones. In 63 of these the abnormal development might be considered to be of the nature of pseudo-epiphyses, 62 of these were at the proximal extremity of the second metacarpal and 21 at the distal end of the first

metacarpal. The other 0 showed true supernumerary epiphyses at the proximal extremity of the second metacarpal with pseudo-epiphyses at the proximal end of the third, fourth and fifth metacarpals and the distal end of the first metacarpal. The appearance of the pseudo-epiphyses varied. In 60 cases bony continuity between the diaphysis and the pseudo-epiphysis was obvious. In the case of the first metacarpal the base of the pseudo-epiphysis appeared to be wholly fused with the diaphysis but in the second metacarpal fusion was present only on the lateral half—a deep cleft separated the inner half. In 23 cases, infants under 2 years of age (distal end of the first metacarpal 10 and proximal end of second metacarpal 13) there was a round ossicle without any evidence of bony continuity with the diaphysis. The latter appearance gave rise to the suggestion that these were true supernumerary epiphyses, though they appeared and fused with the diaphyses before the normal epiphyses showed any sign of an ossific nucleus. It may be that a bony bridge existed though it was undetectable.

The possibility that these rounded ossicles developed from a separate ossific nucleus cannot be denied. In support of this is the fact that in two cases infantile rickets was present and the diaphyseal border adjacent to the nucleus showed some blurring while the diaphyseal extremities of the other diaphyses without such nuclei were clearly defined. In two cases the nuclei were of greater density than the diaphyses even when bony continuity was present, and I have shown (see Fig. 52) that some epiphyses, particularly of the terminal phalanges, often exhibit a greater density than the other normal epiphyses as a variation of the normal. They fuse at the same time as the other epiphyses and become indistinguishable. So marked is the density that one author has misinterpreted it as representing avascular necrosis of the epiphyses. In the condition of multiple chondromata it is the epiphyseal bearing extremity of the diaphysis which shows radiographic evidence of chondromatous metaplasia. In two cases of this dystrophy the diaphyseal extremity bearing the pseudo-epiphysis shows chondromatous metaplasia.

The impression is created by the radiographic study of these cases that separate additional osseous nuclei may develop in the first and second years of life and fuse before the osseous nuclei for the normal epiphyses appear. As will be seen later in certain dystrophies additional osseous nuclei develop soon after the diaphyseal nuclei, remain without bony union until puberty and then unite with the diaphyses a year or so before the normal epiphyses fuse.

Posener, *Walker* and *Weddell*, examining the radiographs of 100 children between the ages of 4 and 8 years, reported the finding of true double epiphyses in 2 cases, the supplementary epiphyses being in both at the distal end of the first metatarsal. On the other hand they reported pseudo-epiphyses in 96 per cent. of the children's hands. In the earlier age periods of my 1,000 cases I found but 8·5 per cent. It is possible with so high a percentage that the so-called pseudo-epiphyses in their cases represented normal diaphyseal extensions which developed after the third year and that though their shape and outline suggested that they had possibly arisen from separate nuclei, radiographs at the earlier age periods of my cases gave no indication of ossification of separate nuclei.

Boden found pseudo-epiphyses of the second metacarpals in 14·7 per cent. of diabetic boys and 5·3 per cent. of diabetic girls.

It has been noted that the metacarpals of mammals—the whale, walrus and seal—exhibit double epiphyses. This is regarded by certain authorities as indicative of retarded growth, a necessity to keep the elements of the limb more pliable. It is further considered that in the primitive formation a proximal epiphyseal nucleus is laid down, but the more accelerated growth of man and animals leads to invasion of the epiphyseal

area before an independent ossific nucleus could be developed *Siegert* 1910 *Köhler* 1912 and *Rochlin* 1929 have discussed this theory in relation to infantile myxœdema and mongolism *Josefson* regards the pseudo-epiphysis as a stigma of endocrine disturbance and *Köhler* considers that their appearance indicates retardation of skeletal growth due to endocrine insufficiency

The radiographic evidence which I have obtained from my cases appears to cast *some doubt on these theories.*

Hypothyroidism is certainly a condition in which retardation of growth is a characteristic feature In this condition evidence of ossific nuclei for the epiphyses is very late in appearing on radiographs—delay of several years may be indicated In the case of the larger epiphyses such as those for the femora, humeri and tibiæ the ossification proceeds slowly from multiple nuclei. The epiphyses consequently do not present the normal homogeneity and strength they are deformed by pressure In none of the cases of hypothyroidism which I have examined did the radiographs of the hands reveal any true supernumerary or pseudo-epiphyses See also factors influencing ossification, p. 20

In the condition of **Chondro-osteo-dystrophy** I found no true or pseudo-epiphyses except in one or two showing a mild type of the dystrophy The condition of **Myositis Ossificans Progressiva** though associated with a characteristic stunted development of the big toe the middle phalanx of the little finger and sometimes of the *bones of the thumb no true or pseudo-*epiphyses were found (see Fig 18) Except in a few isolated cases the same was true in the cases of **Rickets Scurvy Hyperthyroidism, Albers-Schönberg s Disease** and **Osteogenesis Imperfecta**, conditions in which normal ossification is seriously impaired. In a case of **Generalised Polyostotic Fibrous Dysplasia** supernumerary epiphyses were seen in the second metacarpals which fused with the diaphyses during the ages of 10 and 11 years

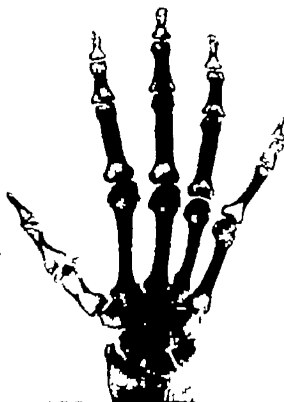


FIG 18. Progressive myositis ossificans. Note short first metacarpal.

Radiographs of all forms of congenital deformities of the hands did not show either true or pseudo-epiphyses

There were certain other skeletal dysostoses in which true and pseudo-epiphyses occurred so commonly that they should be regarded as a feature in these conditions.

I have shown that the bones of the hand in **Cranio-cleido-dysostosis** present radiographic appearances which are very suggestive if not characteristic (see Fig 19). The terminal phalanges *do not develop the prominent cancellous tuft as in the normal*

phalanx instead these phalanges tend to taper from their bases to their free extremities. Later they may be surmounted by a slightly expanded and rounded head. This is also seen in the hand of the adult cretin (see Fig 37) The middle and proximal phalanges of the fingers have additional epiphyses at their distal extremities which fuse with the diaphyses usually before the age of 4 years—those at the distal end of the middle phalanx of the little fingers being the last to fuse. The proximal epiphyses at the base of certain phalanges notably the middle phalanx of the index and little fingers, and the proximal phalanx of the first and fifth toes and less marked, the distal phalanges of the index, middle and little fingers, exhibit an unusual development. From the distal



Fig 19 *Radiograph of hand in a case of cranio-cleido-dysostosis, boy aged 10 years.*



Fig 20. Radiograph of hand in a case of *peripheral dysostosis in a girl aged 8 years. Not* short ulna as well a unusual ossification of phalanges.

surface of the proximal epiphyses a cone-shaped prolongation grows towards the diaphysis and eventually is surrounded by the expanded base of the diaphysis. In the case of the little finger and toe irregular development of the diaphysis of the middle or proximal phalanx sometimes results in bending and shortening of the involved finger or toe The terminal phalanges of the big toe and thumb appear to be developed from two nuclei, the proximal representing the epiphysis, being in the case of the big toe the larger and, in the case of the thumb, as large as the distal diaphyseal element.

This development of both phalanges of the great toe leads to this digit being stunted in its growth. These irregularities in growth are associated with supernumerary epiphyses at the proximal ends of the second and fifth metacarpals. These show the characteristic features of the base of the normal diaphysis and contribute to make the metacarpal of normal length. Though they do not fuse with the diaphysis until puberty

they fuse long before the normal epiphyses of the phalanges and metacarpals have united with the diaphyses.

There is a dysostosis which often affects only the long bones of the hands. I call it **Peripheral Dysostosis**. In mild cases only one or more of the phalanges may show evidence of it and this evidence is secured only accidentally by the radiographs of the part in search for fracture. In cases presenting severe degrees of the condition the growth of the long bones of the hands and feet is so seriously affected that evidence of the dysostosis is detected clinically by the unusual shortness and some bending of the involved fingers. The bones of the forearm and leg may also show evidence of defective growth in such cases; the patella may be absent.

Radiographically the terminal phalanges (see Fig. 20) are seen to be represented by two osseous nuclei; the proximal epiphyseal element being larger than the distal diaphyseal element. As in cranio-cleido-dysostosis the terminal segment is somewhat cone-shaped and the tuft of cancellous tissue is not developed. From the distal surface of the epiphyseal segment a slender cone-shaped prolongation grows into the base of the diaphysis. The latter, at first indented at the site of contact, later appears to expand to accommodate the epiphyseal extension. The changes are most marked in the middle phalanges which also show evidence of fused distal epiphyses. In these phalanges there is complete envelopment of the cone-shaped epiphyses by the expanded sheath-like base of the diaphysis, resulting in marked shortening of the phalanx. In some cases the growth of this diaphyseal sheath is irregular; only one side appears to develop, the joint surface becomes oblique and as a result we have an unusual bending of the shortened finger. The impression is given in a few cases that the two epiphyseal elements fuse to form a central core with the diaphyseal sheath wholly or partly surrounding it. The proximal phalanges show distal epiphyses which fuse at an early age and proximal cone-shaped epiphyses with their tapered extremity enveloped by the base of the diaphysis. The distal epiphyses of the metacarpals show similar but less well-developed characters. Supernumerary epiphyses are seen in the first, second and fifth metacarpals which, as in cranio-cleido-dysostosis, retain their identity until puberty and then fuse before the normal epiphyses do. Somewhat similar changes in the phalanges are suggested in the radiographs of patients with the syndrome described by *Ellis* and *Van Creveld* in which **Polydactyly, Chondro-dysplasia, Ectodermal Dysplasia** was associated with congenital morbus cordis. *Senturias* have described a patient aged 30, who had dystrophy of the nails, arthrodysplasia of elbows and congenital absence of patellæ. Similar irregular development of the epiphyses is seen in **Kaschin-Beck's Disease** and in the conditions which *Beinberg* and *Graznanski* have called **Multiple Osteochondropathy**, but in these conditions pathological fragmentation of epiphyses are the essential lesions (see pp. 62 and 63).

In the condition of **Arachnodactyly** true supernumerary epiphyses are to be seen in the phalanges and metacarpals of the long slender fingers. In the very unusual dystrophy described by *Ellis*, which has been referred to as an example of **Albers-Schönberg's Disease** (marble bones or osteopetrosis), though it does not present the characteristic radiographic features of this disease, well marked extra epiphyses were shown at the proximal extremities of the second and fifth metacarpals and all metatarsals.

In that type of multiple chondromata in which the phalanges and metacarpals are involved (it includes **Ollier's Dystrophy**) the chondromatous dysplasia affects the diaphyseal extremities from which growth is most rapidly proceeding and which bear the epiphyses. In the severe degrees of the dystrophy—chondromatosis—the epiphyses are also affected[22]. In two of the five cases which I examined extra epiphyses were

present on the first and second metacarpals and the distal extremity of the diaphyses of the first metacarpals exhibited chondromatous irregularity.

In another unusual dystrophy I recorded,[44] which affected all the epiphyses of the body and was ultimately associated with a severe degree of scoliosis and bilateral coxa vara, radiographs of the hand at the age of 5 years (23/5/35) showed all the epiphyses for the long bones except the terminal phalanges of the fingers and the proximal extremity of the first metacarpal. Most of these epiphyseal nuclei were laid down in much denser bone than normal. By 10/4/37 no further epiphyseal nuclei had appeared though the existing ones had grown and those which were dense had become denser. By 22/10/40

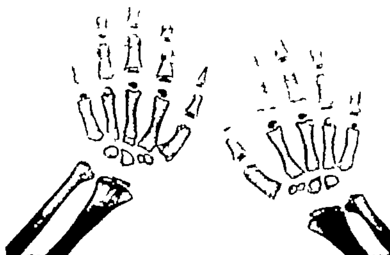


Fig 21 Radiograph of hand of a case of an unusual dystrophy showing dense epiphyses before and after fusion, girl aged 10.

(see Fig 21) the proximal epiphyses of the proximal phalanges on the left hand had fused with the diaphyses but those for the index and middle fingers had lost their density and exhibited the normal cancellous structure of the diaphyses. On the right hand the epiphyses for the ring and little finger had fused and lost their density but those for the index and middle fingers retained their density and separate entity. A minute proximal ossific nucleus, representing the epiphysis for the first metacarpal, had appeared but none were yet visible for the terminal phalanges of the fingers. By 17/6/42 the patient, being now 12 years of age, all the epiphyses previously shown, with the exception of those at the proximal extremity of the first metacarpals and some smaller ones which had appeared at the distal extremity of these metacarpals, had completely fused with the diaphyses and only the epiphyses at the distal extremity of the second and third metacarpals on both hands and the one on the proximal extremity of the proximal phalanx of the right hand had retained the unusual density. It was apparent that this too was becoming less. No epiphyses have appeared on the terminal phalanges of the fingers of either hand. All the larger epiphyses of the skeleton have also fused.

Examination of the radiographs of the hands of true midgets varying in ages from 18 to 36 revealed that 4 of the 20 had supernumerary epiphyses for the first, second and fifth metacarpals. In one male patient aged 22, who was 2 feet 11½ inches in height,

none of the normal epiphyses of the hand or wrist or the supernumerary epiphyses in the proximal end of the second metacarpals showed any evidence of bony union though the extra epiphyses at the first and fifth metacarpals had fused but the line of fusion was obvious. The appearances were similar to those shown in Fig 10

Of the 11 cases of **achondroplasia** 4 showed supernumerary epiphyses of the first and second metacarpals In one case at the age of 1 year no ossific nuclei for epiphyses could be seen on the radiograph but at the age of 6 all the normal epiphyses were present as well as supernumerary epiphyses for the first and second metacarpals the latter having the appearance of commencing fusion

Fusion of epiphyses and diaphysis begins to take place about the sixteenth year in females and the eighteenth year in males, commencing with the terminal phalanges, then the middle and then the proximal. Osseous nuclei of the epiphyses of the heads of the second third, fourth and fifth metacarpals (the distal extremities) and the base (the proximal extremity) of the first metacarpal appear towards the end of the second year of life those of the second third and fourth appearing before that of the first.

By the time all the epiphyses for the metacarpals have appeared the epiphyses show on the radiograph as round or ovoid cancellous bodies having a fine reticulate structure The proximal epiphysis of the first metacarpal is at this stage hemispherical with its flattened distal border approximated to the proximal end of the diaphysis. Before fusion with the diaphysis the epiphyseal lines of the second third, fourth and fifth metacarpals are not on the same plane—the diaphyses have an undulated distal surface opposed to a reciprocal surface of the epiphysis so that on the radiograph the epiphyseal line appears to be broken in some places and double in others. The epiphyseal line of the first metacarpal is straighter and more uniform.

Fusion between epiphyses and diaphyses occurs about the eighteenth year

The ossific nuclei of the carpal bones usually follow a definite order in appearance Here again, the female is usually well in advance of the male though variations occur One has seen marked dissimilarity in the rates of ossification in like female twins The first nucleus to appear is that for the os magnum (os capitatum) This may be present at birth but usually appears about the fifth month and is followed soon after by the appearance of the unciform (os hamatum) so that by the end of the first year the nuclei for these two bones are distinctive During the third year of life the nucleus for the cuneiform (os triquetrum) appears, and by the time the child has reached the age of 4 years the fourth nucleus, that for the semilunar (os lunatum) has appeared. The next nucleus to appear is that for the scaphoid (os naviculare manus) which is usually to be demonstrated on radiographs of children during the fifth year The nucleus for the trapezoid (os multangulum minus) appears soon after and this is followed by the nucleus for the trapezium (os multangulum majus) so that by the end of the sixth year osseous nuclei for all the carpal bones except the pisiform (os pisiforme), can be shown. The latter nucleus appears about the tenth year of life

Instances have been met with in which ossification of all these carpal nuclei was shown on the radiograph at a much earlier age It is not uncommon for all of them except the pisiform, to be shown by the age of 4 years.

The osseous nucleus for the distal epiphysis of the radius may be present at birth and can generally be shown on radiographs by the end of the first year of life but the epiphysis for the lower end of the ulna does not appear until about the fourth year

When these nuclei for the carpal bones first appear they are shown on the radiograph as small round or ovoid opacities with an ill-defined border gradually they assume a rounded shape with a fairly well-defined border and a faint finely reticulated structure

By the time all the nuclei have appeared the os magnum and unciform are beginning to show moulding which will ultimately result in their typical shape

The times given for the appearance of the nuclei for the epiphyses are the average times at which they were seen in the radiographs I have taken of several thousand cases seen at the Carnegie Infant Welfare Centre Birmingham. Cases showing acceleration or retardation were met with in which the cause was not ascertained

Sawtell is of the opinion that the rate of ossification is more rapid in the foot and ankle than in the hand and wrist and that irregularities of ossification are more common in the foot.

Buonsanti did not find any definite departure from the normal ossification of the epiphyses in tuberculosis, active inflammatory diseases, constitutional diseases tumour or acquired deformities.

P Lewin[5] considers that heredity circulatory changes trauma, infection diet, ultra violet radiation, exercise or muscular effort, fresh air endocrines, obesity and chemicals all influence the rate of ossification.

Pryor Davies and *Parsons* have also contributed interesting articles on the subject of ossification of epiphyses as shown by radiography

Adult. Radiographs of the hand of an adult show a mushroom-like expansion of the distal extremity of the terminal phalanges which has a coarse reticulate structure —this expansion is rather larger and broader in the male than in the female. The shafts of the phalanges which show a gradual expansion to the base have concave lateral borders the cortex shows a thin layer of compact tissue while the base has a fine reticulation The middle and proximal phalanges show definite compact tissue in the cortex of the shafts, the upper and lower thirds having a fine reticular structure which becomes coarser as the middle third of the medulla is approached In the latter situation the cancellous structure may appear to be broken down, and areas devoid of cancellous trabeculations may be seen The metacarpals show the characters of the larger bones, *i.e.*, well-defined compact tissue of the shafts with little trabeculation of the medulla but a fine cancellous reticulation of the proximal and distal extremities with no compact periphery The carpal bones all exhibit the same fine cancellous structure throughout with absence of cortical density or central cavitation

Radiographs of the adult hand usually show on the palmar aspect two sesamoid bones on a plane with the head of the first metacarpal bone and one on a plane with the head of the fifth metacarpal but in some cases additional sesamoids may be present. Thus two may be seen at each of the metacarpo-phalangeal joints except the third, one at the interphalangeal joint of the thumb and the terminal interphalangeal joint of the index finger Tender superficial nodules on the palmar aspect of the other interphalangeal joints may suggest the presence of further sesamoid bones but such are not revealed by X ray examination. In one case seen by the author a swelling at the site of the sesamoid at the base of the second metacarpal was a facetted sesamoid half an inch in diameter Its bulk had begun to impair the grip

CONGENITAL DEFORMITIES

The congenital deformities met with in the hand are many and various. Some appear as amputations at various levels, *i.e.* the terminal phalanges or the middle phalanges or the metacarpals. One several, or all of the digits may be missing Extra digits may be present, and dichotomous branching of the bones may be shown

As a bilateral deformity the hand may show a digit in the position of the thumb which has the clinical and radiographic features of a little finger—three phalanges of similar build to those of the little finger—the 1st metacarpal having an epiphysis at

both ends (see Fig 22). This is probably representative of a familial defect. The father of the patient had a double thumb

Thumbs with three phalanges have been recorded by *Campbell*,[3] *Schrader* [2] *Grynkrant* and *Ogilvie* [2]. *McGregor* has recorded a case showing two thumbs, one in the normal position with three phalanges and another at right angles with two phalanges—the metacarpal having a lateral head branching at right angles from its shaft. In my collection there are radiographs of children with congenital absence of the radius and the thumb

Examples of other deformities have been illustrated in papers by *G D Kohler Blackett Politzer Jones* and *Roberts Partridge Cave Belot Kimpel*, and *Nebout*. Numerous radiographs illustrating congenital lesions of the hand are given in the paper by *Pires de Lima*



Fig 22. Thumb with three phalanges resembling little finger in characters. Familial.

Of the many developmental deformities which show hereditary transmission, that described as Brachydactyly was the first to be demonstrated as illustrating Mendelian inheritance. In this condition the fingers are only about half the size of the normal and afflicted individuals show stunting of the limbs and are accordingly handicapped in their struggle for existence but nevertheless they show an increase in fecundity. The abnormal family investigated by *Drinkwater* was very prolific, the number of children in nine families averaging eleven each. A normal woman had forty five descendants while a brachydactylous woman in the same family had ninety-nine descendants. They appear to marry more frequently than their normal relatives and always take normal mates. In 1905 *Farabee* had recorded the distribution of the deformity in an American family from Pennsylvania. *Drinkwater* traced members of this family through six generations. In this family (see Fig 23) the middle phalanx is very short and has become ankylosed to the base of the terminal phalanx. The most important feature is the absence of the epiphysis at the base of the second phalanx. The epiphyses may also be missing in some cases from the terminal phalanx the second and third phalanges consisting at first of a single piece of cartilage. The metacarpal bones are also more or less abnormal but the metatarsal bones are unaffected

The abnormal hereditary factor influences the development of the tubular bones of the hands and feet but not with the accuracy which we see in the normal, for afflicted individuals exhibit some variation in the form of the stunted bones. Thus in one of the families which I investigated some showed a very stunted middle phalanx while in others no representation of a middle phalanx could be detected (see Figs 23 and 24). This variation in the degree of abnormal development is seen in most of the families showing hereditary skeletal defects as will be seen from a survey of the illustrations of the published cases

An unusual form of brachydactyly is shown in Fig 25 Erosion of the tuft of the terminal phalanx is not an uncommon feature—it appears to be associated with under nourishment and is usually small in extent but in the case illustrated marked shortening

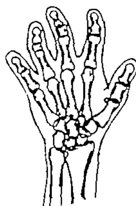


Fig 23. Brachydactyly Tracing of radiograph showing (a) absence of epiphysis at base of terminal phalanges; (b) stunted development of middle phalanx with absence of its epiphysis, in the thumb middle and ring fingers; (c) fusion of stunted middle phalanx with the terminal phalanx of the index finger; (d) total absence of middle phalanx in little finger

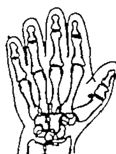


Fig 24 Brachydactyly Tracing of radiograph showing absence of the middle phalanx from all the fingers and stunted proximal phalanx of the thumb. (This tracing was taken from the radiograph of the hand of the mother of the patient whose hand is delineated in Fig 23.)



Fig. 25. Brachydactyly due to defective growth of dia[illegible] rminal phalanges.

of the fingers and the big toes [illegible] from a most [illegible] n and compression of the diaphyses of the termin[illegible] It was [illegible] ld [illegible] se of fracture of the middle metr[illegible]

In the family investigated by the author[44] very irregular distribution of brachydactyly of hands and feet was noted in the members. The brachydactyly was in part

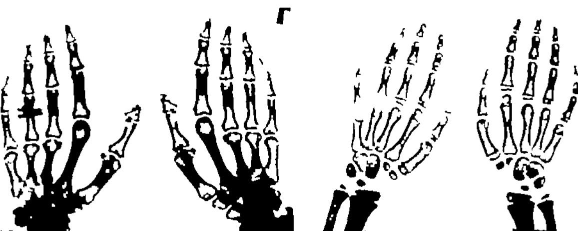


Fig 26. Brachydactyly Familial Note irregularity in disposition of stunted phalanges and metacarpals.

J. H., aged 38.
Feet. Right. Metatarsals, 3, 4 and 5 short 1st very stunted and deformed with pressure deformity on base of 2nd; head of 2nd deformed. Extra ossicle against cuneiform
Hands. Large terminal phalanges for the fingers. Short ones for the thumbs. 3, 4 and 5 metacarpals short

J. W., age 6.
Feet Deformity of base of 1st metatarsal with pressure deformity on base of 2nd.
No other recognisable deformity yet.
Hands. Metacarpals of normal relative size but the epiphyses of 3, 4 and 5 are beginning to fuse with diaphyses and growth in these will cease. Clinically no sign of defect in hands.

brought about by a familiar tendency of certain epiphyses to prematurely fuse with the diaphyses and bring growth to an end in those particular bones The influence of the unaffected mate was shown by the alteration in the distribution and extent of the defects. In another family investigated by the author[45] with brachydactyly mainly

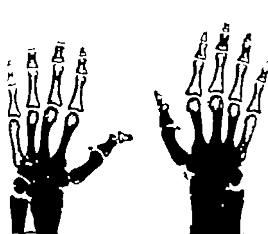


Fig 27 Brachydactyly Familial. Associated with bilateral defects in ossification of femoral head and resulting coxitis (see Figs. 203 A–B).

associated with short terminal phalanges and defective growth of the middle phalanges there gradually developed from adolescence a bilateral coxitis which in the adults was of a very crippling nature

Two families investigated by *Drinkwater* exhibited a condition which he described as Minor Brachydactyly the skeletal defects being of a lesser degree.

Craig and *Drinkwater* have described a condition of brachydactyly associated with hereditary absence of phalanges (Hypophalangy) through five generations In this family the defect (see Fig 28) consists in an entire absence of the distal phalanges from each digit except the thumb and big toe and an extremely abortive condition of the middle phalanx in the same digits The finger nail is absent. The thumb abnormality is of a different type from that seen in the fingers and is affected independently The condition



FIG. 28. Hypophalangy Tracing of radiograph showing (*a*) absence of terminal phalanges from all the fingers; (*b*) Symphalangy of terminal phalanx of thumb; (*c*) very diminutive nuclei for middle phalanges of fingers (Craig and Drinkwater).



FIG. 29. Brachydactyly associated with abnormally short and long phalanges. Tracing of radiograph showing (*a*) ulnar deviation of the index and middle fingers due to obliquity of base of proximal phalanx of index finger; (*b*) relative shortening of the middle finger due to stunted development of all its phalanges, the proximal phalanges of the other fingers being elongated, their middle and distal phalanges being stunted; (*c*) two un-united stunted nuclei for the middle phalanx of the middle finger (*Drinkwater*).

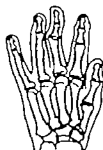


FIG. 30 Symphalangy (*Cushing*). Phalangeal synarthrosis (*Drinkwater*). Tracing of radiograph showing (*a*) fusion of proximal and middle phalanges of the ring and little fingers; (*b*) irregularity of articular surfaces of the proximal interphalangeal joint of the middle finger Talbot family (*Drinkwater*).

is bilaterally symmetrical. The inheritance is not strictly Mendelian in all its features and there is no correlated shortness of stature such as is seen in the members of the other brachydactylous families

Drinkwater has traced through four generations a further developmental abnormality in the fingers In this family (see Fig 29) the ring finger appeared to be abnormally long compared to the other fingers

Radiographically it was shown that this was due to an increase in length of the proximal phalanx of the ring finger and shortening of the index and middle fingers due to abnormal stunting of their phalanges. Owing to the oblique development of the base of the proximal phalanx of the index finger the index and middle fingers project away from the thumb. *Drinkwater* and *Cushing* have described a condition of Phalangeal Anarthrosis, now called Symphalangism. *Drinkwater* found the condition present in a direct descendant of John Talbot, first Earl of Shrewsbury who was killed in battle in 1453 and it has been established that the skeleton of the latter exhibited like abnormalities which have been handed down as a Mendelian dominant for more than 500 years

In this condition of Symphalangy (see Fig 30) radiographs show fusion of the proximal and middle phalanges of the little and ring fingers with irregularity and diminution of the joint space between these phalanges of the middle finger which joint is much

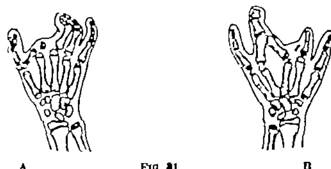
swollen. The distal interphalangeal joint is preserved in all fingers All toes except the big toe how like fusion. These abnormalities lead to inability to close the affected fingers

Cushing has given an account of a family showing a like hereditary deformity

As with other hereditary deformities, variation in the extent of the deformity occurs in different individuals.

Manson has investigated the member of a family which had representatives living in Aberystwyth about the beginning of the nineteenth century Of sixty descendants twenty seven were affected. Members showed a variable degree of webbing of the third and fourth fingers and an additional toe on each foot

Bateson, in speaking of Syndactyly (see Fig 31 A and B) (which refers to bone fusion but is sometimes used to denote webbing of the soft tissues only for which the



A FIG 31 B

A. Syndactyly (Zygodactyly). Tracing of radiograph showing (*a*) webbing of the middle and ring fingers, thumb and index fingers; (*b*) stunted development of the phalanges of the index, middle and ring fingers; (*c*) abnormal transverse position of phalanx between the head of the first and second metacarpals.
B. Tracing of radiograph showing (*a*) webbing of middle and ring fingers; (*b*) stunted development and absence of osseous elements.

term **Zygodactyly** has been suggested) states that digits three and four in the hand and two and three in the foot, are the ones usually united and that the union is greatest peripherally

R H Sankey has investigated a family in which the members show an hereditary maldevelopment of the ring finger

Lewis has given an account of the references and abstract of 18 families exhibiting the condition of Polydactylism (see Fig 32A) or excess of digits above the normal He states that in man it is most frequently post-axial (towards the little finger or toe) but many varieties are known. Thus it may be pre-axial (towards the thumb or great toe (see Fig 32B)) in which case the hereditary tendency is probably less marked or the reduplication may be central There are several grades of the deformity (1) Small appendages in the form of fibrous skinclad nodules which may or may not contain bone and attached as a rule post-axially (2) Bifurcation of normal digits with complete or partial reduplication of the part. The bifurcation may be of any extent or may originate at the distal end, middle or proximal end of either the digital bones or at either of the joints *In the complete form there is complete reduplication of the digit as far as* carpus or tarsus The dichotomising digit is as a rule symmetrically placed about a central line and is usually though not invariably laterally disposed. (3) Irregular or intermediate forms In one of the cases seen by the writer the child had six digits on each extremity and this was associated with stunted development of the humeri and femora and a defect in the mandible This would appear to be the reverse to the giant

mentioned in the Bible (2 Sam. xxi 20 "And there was yet a battle in Gath, where was a man of great stature that had on every hand six fingers and on every foot six toes four-and-twenty in number and he was also born to the giant) It is stated that he was one of four men of exceptional stature—sons of a giant.

Irregularity in the premolar area is sometimes associated with polydactyly

K Bonnevie describes a type of Polydactyly in man. The extra finger arises from the *base of the little finger and the metacarpal bones are normal. The families showing it*

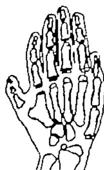


Fig 33A. Polydactyly (post axial). Tracing of radiograph showing additional little finger with dichotomous development of fifth metacarpal



Fig 33B. Tracing of radiograph showing additional terminal phalanx of thumb.

are distributed all over Norway and are probably descended from a common ancestor about 300 years ago. Many other developmental deformities which show hereditary transmission have been recorded.

Other families have been investigated in which members exhibited supernumerary fingers and toes. The extra digit with its three phalanges has been seen on all four extremities in some members while other members exhibited one or more normal extremities

R W G Ellis and *S Van Creveld* have recorded a syndrome which is characterised by Ectodermal Dysplasia, Polydactyly Chondrodysplasia and Congenital Morbus Cordis.

J K Breitenbecker has given an account of hereditary shortness of thumbs The terminal phalanx of the thumbs and the second phalanges of the fingers are very short with a very broad and short nail. The condition was traced as a Mendelian dominant through five generations

A number of other observers have recorded similar cases (see Fig 26).

Weitzner has published a case of hereditary bilateral ankylosing arthropathy of the hands and wrists associated with synostosis of the astragalus and navicular

In a paper with the title of "Hereditary Malformations of the Hands and Feet, *Thomas Lewis describes the appearance in the so-called Split Foot and Lobster Claw* He points out that a definite description of it is difficult or impossible owing to the remarkable variation presented by the separate deformed individuals of the same family The fundamental or most constant lesion appears in the form of cleft feet, a lesion which is symmetrical as regards the two sides of the body Radiographically considerable variation in the form of the bones is shown. The variation in the degree of the defect is wide in its range it may involve at least four toes and may spread to the tarsus or even to the bones of the leg

Those digits are most affected which lie towards the central cleft and the defect is

shown in a distal bone before it appears in a proximal one (see Figs. 33 A and B) The hands which have never been recorded as affected in the absence of a foot lesion show one or two main types of deformity Either it is analogous to the foot lesion the defect falling mainly upon the centre of the hand or it affects the pre axial border of the hand As a rule the phalanges of at least two or three digits are absent In rare cases the carpus is affected. In the presence of foot malformation one or both hands may escape entirely The hands may show polydactylism and syndactylism. The heads of the metacarpal may be joined by regular cross-bones (considered to be phalanges) which articulate with them as in Fig 33A. As a whole the deformity shows segregation in high degree



FIG. 33A. Tracing of hand of same patient showing ( ) absence of all the fingers except the little finger; (*b*) absence of one metacarpal; (*c*) stunted development of one metacarpal; (*d*) transverse position of a phalanx between the heads of the fourth and fifth metacarpals.



FIG 33B. Split Foot or Lobster Claw Tracing of radiograph showing absence of metatarsals and phalanges for the second, third and fourth toes.

no undoubted case having as yet been recorded of its missing a generation to reappear in the next.

It has been recorded in association with cleft palate. He gives an account of six families which have been recorded

Lewis and *Embleton* have considered 180 cases of Split Foot. They point out that both the hands and feet show great functional ability and accuracy The handwriting and needlework may be excellent.

The condition is not a very rare one. It has been described as club foot, split foot and hand hereditary split foot, crab or lobster claw Perodactyly Peromanus, Peropod Perochirus Ectrodactyly Splatfuss, Hummer Schere, *main ou pied en pince de homard*

They point out that the great functional capacity of the deformed limbs is in itself a proof of the early laying down of the hands and feet in their malformed state. A deformed man may have deformed children by separate and normal wives and therefore the deformity must exist in a potential form in the germs of the father The normal regularity of conformation and the morphological resemblance of hands and feet can only be explained by assuming that, in addition to the presence in the *germ cells of* determining factors for the constituent parts of the extremities, there must exist factors determining the arrangement and growth of these, either separately or collectively

The extermination of hereditary split foot takes place by a proportionate decrease in the number of deformed offspring arising from deformed parents from one generation to the *next.* The deformity has its origin in a *sport* which takes place in the parental germ cells or their precursors, probably the latter The transmission of hereditary split foot does not follow the laws of Mendel. It is true that the deformity segregates, but it appears to a diminishing extent in succeeding generations It shows no tendency to skip generations

In his paper on "Split Foot or Lobster Claw" *K. Pearson* states that "An old man told my informant that a boy with deformed hands was a descendant of the 'Cleppie Bells.' This was a family one of which had assisted as Sheriff's officer at the drowning of the Wigton Bay martyrs in 1685. On that occasion the officer Bell said to a young maid, Margaret Wilson, 'Will you not say "God bless King Charlie" and get this rope from off your neck?' 'God bless King Charlie, if He will,' she responded. Whereupon he said 'Clep down among the partens and be drowned.' Thus he was called 'Cleppie Bell' and his descendants have ever afterwards suffered from a deformity of the hand although sometimes a generation is missed over."

Pearson also gives a somewhat different version taken from Sir Andrew Agnew's "*The Hereditary Sheriffs of Glasgow.*"

The deformity known as Club Foot appears to show hereditary transmission in a large percentage of cases.

Acheiropodia or absence of hands and feet is described in a family from Brazil by *Peacock*.

Apert has described a condition which he calls Acrocephalosyndactylia in which syndactyly is associated with malformation of the cranial bones.

Patients with the complete Laurence-Moon-Biedl Syndrome show polydactylism usually asymmetrical and post-axial (*e.g.*, towards the little finger or toe) syndactylism, deformity of the skull, sometimes other skeletal defects, dystrophia adiposo-genitalis, atypical retinitis pigmentosa, often without the concomitant hyperpigmentation, mental deficiency, retarded growth and familial incidence, the members exhibiting different degrees of these features; one generation only may be affected.

An hereditary deformity of the hands which may lead to dispute is the short metacarpal. The metacarpal which most commonly shows this deformity is the fourth, but families with members showing bilateral shortening of the third, fourth and fifth metacarpals associated with short metatarsals have also been met with. In the families investigated by the author[44] it was due to an hereditary tendency for premature fusion of certain epiphyses, a feature in the defects in Osteogenesis Imperfecta (see Fig. 84). *Cartay* has illustrated a paper showing these multiple deformities.

In one instance in which only the fourth metacarpal was short, the deformity was attributed to an injury, but a radiograph of the opposite hand showed a like deformity. Shortening of a metacarpal can result from injury, or disease (such as Tuberculosis, Typhoid, Smallpox, Syphilis, or Leprosy) of the metaphysis of the growing bone, and the affected metacarpal, when completely healed, may have a similar appearance to the hereditary form. The middle metacarpal appears to be the chief one to be shortened by damage to its metaphyseal region. *Newmark* has described ill-developed metacarpals in Hereditary Syphilis.

Fusion of the phalanges of the thumb and of the big toe, and irregularities of the heads of the first metacarpals and metatarsals occur in Progressive Myositis Ossificans.

Associated with Cutis Verticis Gyrata phalanges of equal width throughout their entire length are found as shown in the illustrations published by *Renander*.[4]

Arachnodactyly. This is a condition of the skeleton which is characterised by increase in the length of the long bones—particularly noticeable in the metacarpals, metatarsals and phalanges in association with deformities of the skull, eyeball (particularly subluxation of the lens) and thorax, with a hypotonicity of the muscles which may suggest amyotonia congenita. The condition was first described by *Marfan* in 1896 but was given this name by *Achard* in 1902. Details of about thirty cases are to be found in the literature. The condition is considered by *Greig*[1] to commence very early in intrauterine life. Looking at the patient one is struck by the deformed head—

a prominent forehead often with marked increase in width between the eyes—the short trunk with a cramped appearance of the thorax and the long slender limbs with fingers and toes appearing to be very much longer than normal

Ingram and *Inglis* point out that the distal phalanges of the outer three toes are turned inwards. In the illustrations of *Ganther* and *Schrader*[1] the very long slender



Fig. 34 Osteogenesis imperfecta. Premature fusion of isolated metacarpals.

limbs and extremities are most distinctive. The radiographs of the hand (see Fig 35) show long slender metacarpals and phalanges. The long bones of the limbs, the metacarpals and proximal phalanges may be abnormally long with the middle and distal phalanges of normal length.

Epiphyses may be seen at the distal and proximal ends of the first and second metacarpals and metatarsals and for all the proximal and distal phalanges

The condition is thought by some authorities to be due to hyperpituitary disorder In the illustrations used by *Albanese* the big toes are very hypertrophied

Examples of marked hypertrophy of the right index finger and the left index and middle fingers are in the collection of specimens in the Royal College of Surgeons Museum, London. The papers by *Young*, *Greig*[1] *Schrader*[1] *Ganther* *Muller*[2] *Albanese* contain good radiographs and photographs of this condition.

CHANGES IN THE BONES ASSOCIATED WITH ENDOCRINE DISORDERS

Tumours of the anterior lobe of the pituitary gland lead to overgrowth of the skeleton, the results depending on the age at which the hyperactivity of the gland develops.

If the hyperactivity commences before the epiphyses have fused general increase

in the size of the skeleton occurs. The radiographs of such a skeleton may show that the bones are of normal shape and structure though considerably enlarged in size, as in the case of the Irish giant, Magrath, whose skeleton is preserved in the Anatomical Department of Trinity College Dublin.

The author radiographed the skeleton of a giant girl who died from pneumonia at the age of 23 years. The radiographs show that the bones, now mounted in the Museum, Anatomical Department, Birmingham University consist of a very thin casing of compact tissue containing little cancellous trabeculation. The epiphyses have all united They are normal in shape proportionate, but very much enlarged in size

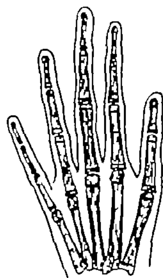


FIG 35. Arachnodactyly Note the long slender metacarpals and phalanges and the additional epiphyses at the distal ends of the first metacarpal and the proximal and middle phalanges.

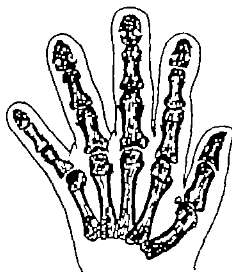


FIG. 36. Acromegaly Note the enlarged tuft of cancellous bone on the terminal phalanges, which are short and as broad as they are long Some of the proximal and middle phalanges show peripheral spikes.

thus the third metacarpal with its phalanges measured 8½ inches in length, the normal measuring only 6 to 6½ inches. Subsequent section of the long bones at post mortem showed that they consisted of thin shells of compact tissue containing loose cancellous trabeculæ.

This case presents radiographic features which are in strong contrast to the radiographs used by *Schinz*, of the hand of a giant, aged 44 years, which show that the epiphyses of the phalanges and metacarpals have not yet fused It is conceivable that in this case some other endocrine dysfunction also occurred an opinion which is supported by a further radiograph by *Schinz* of a giant girl 22 years of age in which the epiphyses have fused

The influence of diabetes on ossification, see p. 20

Acromegaly When the hyperactivity of the pituitary gland occurs only after fusion of the epiphyses the radiograph shows that the cancellous tufts of the terminal phalanges hypertrophy small spurs develop from the shaft, and the tuberosities of the phalanges show increased prominence (see Fig 36). Small detached ossicles may also develop in the neighbourhood of these peripheral spurs.

Progeria This condition was first described by *H Gilford* as one of "immaturity upon which has descended the blight of premature senility" No better description could be given for the development of the body which at birth appears to be normal slows down and even before the age of 10 shows signs of premature senility The patient is dwarfed yet in the early years perhaps unusually bright and alert and has an excessive total energy output. The head becomes so characteristic that children affected appear to bear a strong likeness to one another The hair becomes thin, whitened and falls out perhaps completely The subcutaneous fat is absorbed and the skin becomes thin shiny then wrinkled. The veins therefore become prominent, the nose beaked, the chin receded, the abdomen protuberant and the umbilicus obliterated The skin over the abdomen exhibits whitish water drop pittings and some brownish pigmented areas The chest is narrow The teeth fail to develop Arteriosclerosis with all its allied manifestations, coronary thrombosis, myocardial and cerebral infarction, hemorrhages characterise and bring to an end the patient often before reaching the age of 10 years

The main radiographic features are narrow cranial sutures, a small mandible with under-development of its processes, small clavicles with a narrow chest. Small slender bones to the extremities, erosion of the terminal phalanges. The vertebral bodies retain the features of the infant—ovoid with marked notching of the anterior surface—separated by discs which are thin centrally but deep anteriorally Coxa valga positions of the femora. All these features indicate delay in ossification In some cases the skeletal features of cranio-cleido dysostosis are present, *i.e.*, wormian bones in the skull as in Fig 432 A, small defective clavicles, etc. Two cases have shown osteochondritis of the femoral capital epiphysis and some degree of fragility or plasticity of the long bones, particularly upper ends of humeri and femora. Characteristic cases have been described by *Mitchell* and *Goltman* also *N B Talbot*

Ateleiotic Dwarfs or midgets are miniatures of the normal Through the kindness of Mr Roper who has charge of a large travelling group of these small people, I have been able to make complete X ray investigations. These bright and attractive people are very graceful in their actions displaying considerable ability in entertaining and giving no indication of endocrine disorder or ill health. The bones and viscera have the shape of the normal, though they are considerably smaller The skeleton in the museum of the Royal College of Surgeons, London, of Caroline Crachami the Sicilian dwarf, who measured only 19¾ inches in height at the age of 9 shows the uniformity of the dwarfing The epiphyses of these midgets unite much later than the normal. The epiphyses of the phalanges and metacarpals of a midget female aged 23 years and measuring 2 feet 10½ inches in height, had not yet fused with the diaphyses, but those of another female midget aged 32 years had united. The epiphyses of a male midget aged 38 years had united, but the line of the epiphyseal cartilage was still clearly defined as a thin dense line. Familial distribution of this dystrophy has been recorded. Though often sterile some have married and had children who have developed normally *Davenport* believes that in ateleiosis as in achondroplasia, there are multiple dominant growth inhibiting factors. He refers to the pedigrees of two well known families of ateleiotic dwarfs in the Tyrol which have intermarried.

Except for size the only departure from the radiographic appearance of the normal skeleton I find is in the phalanges of the hand, more particularly the middle phalanges In place of the normal cancellous trabeculation of the proximal half these showed a characteristic fine stippling In none of these small people did the size or shape of the sella turcica suggest any abnormality: it appeared to be proportionately smaller than the normal, but cases have been recorded by a number of observers under the title **Lorain type of Infantilism**, in which the dwarfing has been associated with pituitary

disorders and abnormalities of the sella. *Lorain, though he did not appreciate the association,* published the first exact clinical description of such a case in 1871. A similar case which had been subjected to exhaustive examination, was described by *Worster Drought, Carnegie Dickson* and *Crockhurst Archer*. They bring evidence to show that a disturbance of the hypothalamic region would be just as likely to produce symptoms of dyspituitarism as would a lesion of the pituitary gland itself. Several clinical cases have been reported in which diabetes insipidus glycosuria, adiposity and Frolich's Dystrophia Adiposo Genitalis have been associated with lesions of the hypothalamus and histological examination of the pituitary has shown no abnormality. Interesting accounts of cases of dyspituitarism of the Lorain type have been published by *Levi* and *Dunlap*. Delayed fusion of the epiphyses is shown in the man aged 45 years who has a Rathke-pouch tumour. *R. A. Rowlands* and *S. L. Simpson* give an illustrated account of the case.



Fig. 37. Adult male cretin, aged 64 years.

Schinz has published an interesting account with radiographs illustrating the features of the skeletons of dwarfs.

Cretinism. The essential radiographic feature is delay in ossification as indicated on p. 20 and illustrated in Figs. 16 A–C. In some cases it is associated with stippling of the epiphyses and calcium deposits (see p. 18). The effect of the retardation of growth is shown in the radiograph of the hand of the adult cretin, see Fig. 37. The epiphyses, late in showing ossification, develop from multiple ossific islands and the large ones are deformed by the pressures of normal function, see p. 269–70.

Achondroplasia. In this condition there may be no definite delay in the appearance of the epiphyses of the hand. Thus in a boy of 1 year of age no nuclei for any of the epiphyses in the hand or the distal end of the radius can be detected—the stage of ossification of this boy as far as the appearance of nuclei for the epiphyses and carpal bones is that of a normal boy of about 10 months. At the age of 6 years, though all the epiphyses of the hand were present including double epiphyses for the first and second metacarpals, only the osseous nuclei for the os magnum, unciform and cuneiform had yet appeared. Ossification at this stage was seen in other achondroplasiacs as early as 2 years. The index and middle fingers usually show radial deviation and the ring and little fingers ulnar deviation, leaving a characteristic V shaped gap between the stubby middle and ring fingers. The appearance of the diaphyses is characteristic. The terminal phalanges of the fingers are a little broader than the normal that for the thumb conical in shape with a broader base than normal. The middle phalanges are as broad as they are long, each with a rounded distal and a flattened proximal extremity.

The proximal phalanges are thimble-shaped, being only a little longer than they are broad and having a rounded distal and a flattened proximal extremity.

There is practically no distinction between the cortex and the medulla—the reticula-

tion of the cancellous structure being more open or coarser than the normal The metacarpals are shorter and thicker than the normal and their proximal and distal extremities are flattened and irregular Nuclei for the os magnum and unciform only are present in the case described: these have a regular round border and are about ¼ inch in size The distal extremities of the ulna and radius present an irregular flattened appearance and, like the metacarpals, appear to have had their extremities broken off and absorbed In the adult the phalanges are all very short and thick with marked expansion of the extremities. The metacarpals are only about twice as long as the heads are broad the extremities are expanded but the shafts, which are only the length



FIG 88. Chondro-osteo-dystrophy Hand of a boy aged 8 years.

of the heads, are thinner than the phalanges and possess concave lateral margins merging as they do into the expanded extremities. The carpal bones show little change, but the lower ends of the ulna and radius show expansion similar to the metacarpals

Chondro and Osteo Dystrophies There is a group of conditions due to faulty development of cartilage and its subsequent ossification which produces marked typical changes in the bones of the hand.

In the condition which I have named chondro-osteo-dystrophy [11] all the bones of the hand develop from multiple osseous nuclei—on the radiograph the epiphyses appear

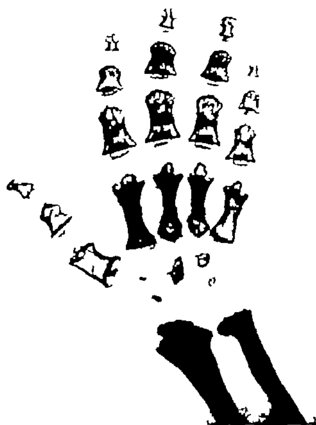


Fig. 39 Chondro-osteo-dystrophy Note irregular ossification.



Fig 40. Chondro-osteo-dystrophy Multiple defect in joint surfaces.

to be fragmented. The diaphyses of the phalanges and metacarpals are altered in shape, being stunted and irregular in outline, particularly at the extremities They are devoid of the symmetry and superlative architecture of the normal. The reticulation of the cancellous bone is very coarse where it is seen, but it appears to be lacking in the medulla of the metacarpals. The osseous nuclei for the carpal bones are also very irregular in outline and may show irregular disposition of additional smaller nuclei around their periphery There is no marked delay in the appearance of the epiphyseal nuclei, but subsequent growth and moulding is very slow and irregular The distal extremities of the ulna and radius and their epiphyses show similar irregularity and deformity (see Fig 40).

The spaces at the joint between the opposing bones are all markedly increased and these bony surfaces are irregular in outline suggesting a marked thickening of the cartilage forming the articular surfaces. In this type of case the whole skeleton shows the same type of irregular development. Many degrees of this dystrophy are seen, see Figs. 38–40 Lesions which escaped attention in infancy may cause considerable crippling with the functions of life later For the purposes of description they are classified into four groups (see pp. 565–9)

Multiple Exostoses. In this condition the bones of the hand usually show t changes which appear to be chiefly confined to the diaphyses but differ fro preceding condition in the fact that the changes occur only in the diaphyseal ext where they may interfere with the epiphyseal growth and even cause premature and consequent shortening and deformity. The reticulation of the cancellous b more open than in the normal phalanges. The diaphyses, instead of having r

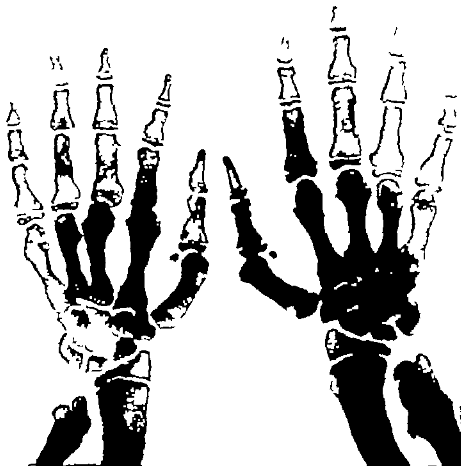


Fig 41 *Radiograph of the hands of a youth aged 15 years showing multiple exosto* Note that the exostoses are developing in different sites from both ends of the diaphy of the phalanges and that none has arisen from the epiphyses. *Where the exosto* has involved the metaphyses, the epiphyses are deformed and premature fusion taken place with resultant shortening of the proximal phalanx of the index finger *the ulna on the one hand. This boy has a brother with similar deformities and his fat* and grandmother are likewise affected. See pedigree in Part II page 374

curved or straight margins, show bony buds or protrusions from the cortex. Wh process involves the metaphyseal surface of the diaphysis the epiphysis may be def and the metaphysis destroyed premature fusion resulting

The metacarpals show similar changes, but the carpal bones, like the epi escape. The articular surface of the lower end of the radius frequently faces i owing to bending of the shaft. This is due to multiple exostoses which have resu marked shortening of the ulna. Multiple exostoses may be seen on the lower th

both bones and premature fusion of either epiphysis may result from its involvement. In some cases the disturbance of growth of the ulna is so great that the latter is less than one-third the length of the radius, and dislocation of the radius at the elbow results (see Fig 99)

These exostoses may grow to a large size and produce great deformity and as they

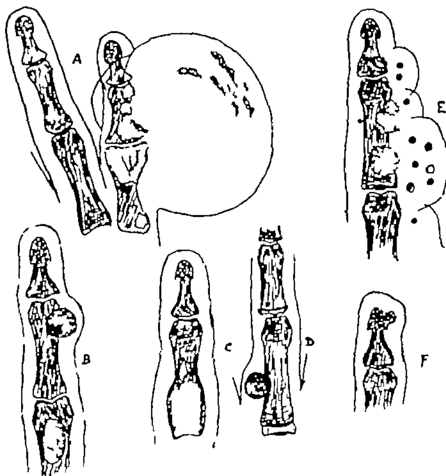


FIG. 42.

A. Multiple enchondromata which caused a large tumour of the little finger Note the fragments of bone in the tumour apparently detached from the cortex of the phalanges.
B. Central and cortical enchondromata of the phalanges.
C. Central enchondroma producing swelling of phalanx.
D Exostosis of the basal phalanx.
E. Multiple hemangioma containing phleboliths associated with enchondromata
F Subungual exostosis.

are closely associated with the joints they may considerably reduce the range of movement.

In some cases sarcomatous changes occur but this development does not take place as frequently as in the multiple chondromata (see general discussion, pp. 573 and 577)

Multiple Chondromata and Enchondromata. In the type of chondrodystrophy first recorded by *Ollier* irregular proliferation and ossification of cartilage take place

in the diaphyses and this results in marked alteration in the radiographic appearances of the bones These are all shown in Figs 42–45 It appears that no irregularity occurs in those bones which have begun to ossify since birth only or in epiphyseal ossification, though the irregularity in the diaphyses is related to the growing ends—and therefore the changes in the phalanges are chiefly in the proximal ends but in the metacarpals at the distal ends. In some severe cases growth disturbances do affect the epiphyses In fact in some cases which I have called **Chondromatosis** cartilage in every part of the



Fig 43 Chondromatosis, see Figs. 100 120 219

skeleton shows marked proliferation with destruction of adjacent bone (see Fig 43) The changes range from increased density of the middle portion of the shaft in the region of the nutrient foramen with small well-defined unossified ovoid or rounded areas to marked bulb-like expansion of shaft with irregular long spicules spreading out from the neighbourhood of the nutrient foramen towards the growing end, sometimes with the shape of a balloon

It should be noted that the nutrient foramina in nearly all the phalanges are definitely enlarged in the proximal phalanx of the middle finger it appears to have been converted into a long trough (see Fig 44 A and B)

This feature of the foramina and the site of the changes in the bony structure lend interest to the theory and experiments of *Bentzon*—a note of which is given in a subsequent chapter (see general discussion in Part II)

the bone (see Fig 43), or only small islands of bone showing normal cancellous reticulation may be seen, as in Fig 45

Individual chondromata may give a cyst like appearance to the bone. If shelled out of their bony casing subsequent radiographs show consolidation of the bone at this site. When growth ceases these enchondromata may show regression or remain in a stationary condition, but they are prone to sarcomatous changes, and any rapid increase in growth, particularly in middle-aged patients, should be viewed with great suspicion (see General Discussion in Part II)

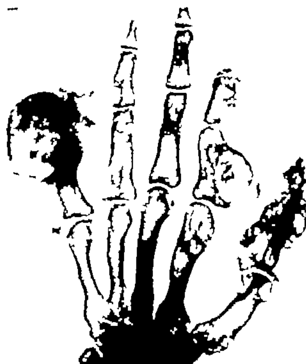


FIG. 43. Radiograph of hand of patient with multiple chondromata. Note the islands of bone in the chondromatous tissue. This is a sign of accelerated growth but not necessarily of malignant metaplasia of a sarcomatous nature.

Myxomata of the phalanges present a somewhat similar radiographic appearance.

Enchondromata of the skeleton may be associated with Multiple Haemangiomata. The presence of the latter is indicated on the radiograph by small round isolated opacities in the soft tissue as in E Fig 42 *Hultén* and *Loven* have described a case of Multiple Haemangio-chondromata in a man of 27 Their radiographs show tumours in the hand and foot and right iliac bone associated with swellings in the soft tissues containing calcified phleboliths. The nodules in the hand and foot had been noted for 10 years. They gradually increased in size but were not painful or sensitive to pressure

Specimens of this condition are to be found in the Museum of the Royal College of Surgeons, Nos. 2101, 1 2 and 3 The condition was described by *Kast* in 1889

In the case of hæmangiomata which involved all the soft tissues of the hand and arm, except for a coarser cancellous structure of the ends of the phalanges, there were no bone changes (see Fig 46)

Sawlozky has also illustrated a case of hæmangioma of the hand.

Simple exostoses as in D Fig 4* showing normal bone trabeculation are also met with in the hand, the most common site being the Subungual Exostosis, as in F Fig 4* The latter often appear to be related to trauma of the expanded cancellous extremity of the terminal phalanx.

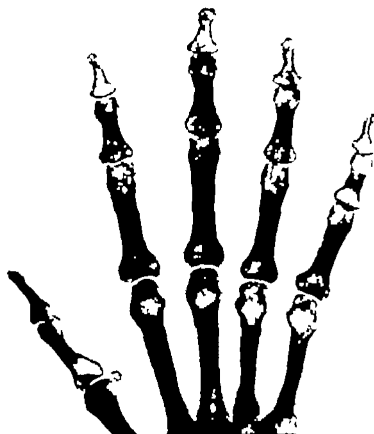


FIG. 46. Clubbing of fingers and coarse cancellous structure in ends of phalanges in a case of hemangioma of soft tissues

LESIONS OF TERMINAL PHALANGES

Avulsion of the posterior fragment at the base of the terminal phalanx produces the condition of **Mallet Finger** Cricketers may suffer this injury in one or more fingers when attempting to catch the ball. The fragment may fail to unite or union may be considerably delayed. Similar avulsion may occur to the posterior fragment from the base of the middle phalanx to which the middle slip of the extensor tendon is attached This causes the collateral pieces to slip on each side as they pass to the base of the terminal phalanx. With this injury the finger cannot be actively extended but when extended passively the collateral slips of the tendon snap back into place The condition is referred to as **Trigger Finger,** though this term is more frequently applied to the lesion in **Teno Vaginitis Stenosans.**

In one case seen by the author the lesion had occurred bilaterally in the middle finger in a youth of 17 without any recognised cause He was a paint stirrer by trade

The avulsed fragments of both hands became avascular and led to a localised erosion about the same size in the adjacent surface of the head of the proximal phalanx (see Fig 47).

An appearance simulating enchondroma may occasionally be met with in the terminal phalanx due to injury which results in an Implantation Dermoid involving the terminal phalanx (see Fig 48A) *Burrows* has described and illustrated this condition in a man of 47 who when a boy of 11 ran a piece of wire into his left thumb A year before the radiograph was taken he noticed a swelling of the thumb and a radiograph revealed a well-defined area of rarefaction at the extremity of the phalanx with an extension towards the base of the phalanx. At operation a collection of sebaceous material was scraped from the bony cavity which was lined with a white glistening stratified epithelium. *R Harris* has also recorded a case presenting the same radiographic and clinical features



Fig 47 Radiograph of middle finger of a youth of 17 years showing avascular fragment from base of middle phalanx with localised erosion opposite in head of proximal phalanx. Bi lateral.

Dittrich has illustrated another condition in a man of 20½ years in which the radiograph showed large ovoid areas of cancellous destruction in the terminal phalanges (see Fig 48B), which were associated with bluish markings on the nails. The pathology of the condition was not ascertained. It is probable that they were of the nature of angioneuromata. **Subungual Glomus Tumour Angioneuroma, Popoff Tumour Glomangioma** ***Neuro-myo-arterial Glomus*** are the names which have been given to a neuro-myovascular structure found in the reticular layer of the cutis, and associated with the heat-regulating mechanism. It is most commonly found in the subungual region. Hyperplasia of these structures produces a bluish or purple-bluish very painful tumour beneath the nail Its nature may escape detection for some time but eventually it produces a characteristic localised pressure absorption of the dorsal surface of the cancellous tuft of the terminal phalanx. Some appear to be associated with trauma. They are of a simple nature and surgical evacuation usually results in cure Cases have been described by *P Masson* and *M Ludin* Malignant melanotic tumours in this site may produce somewhat similar changes and though usually of slow growth, ultimately reveal their identity by the formation of pigmented spots and distant metastases.

In Pringle's Disease (Sebaceous Adenoma) small areas of cancellous destruction and irregular periosteal thickening of the phalanges may be associated with tuberose sclerosis of the brain, phakoma in the retina *I Areus* has described three such cases. Irregular periosteal deposits in a case of tuberose sclerosis has also been described by *G Hall.* He regarded it as a case of melorheostose but on examination of the material I was unable to confirm this

Erosion of the cortex of proximal phalanges and metacarpals near the growth cartilage has been seen in association with general osteoporosis in cases of leucaemia.

Well-defined circular or semicircular areas of destruction of cancellous bone—most commonly at the base of the terminal phalanges the head of the middle phalanx and the lateral borders of its base—are met with in Chronic Gout as in D Fig 48 Occasionally

the head or base of the phalanges appears to have suffered an irregular erosion due to the collapse and absorption of the walls of the areas containing these gouty deposits. Radio-

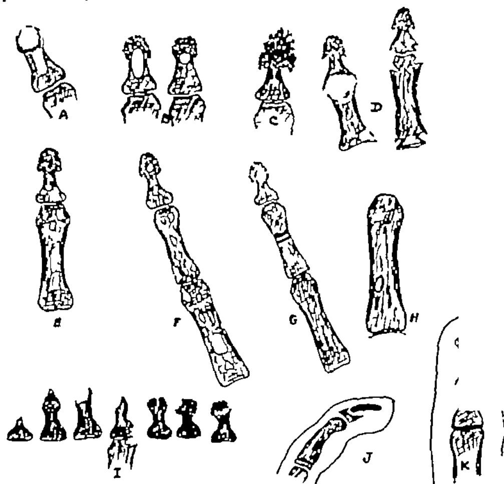


Fig. 48.

A. Implantation dermoid in terminal phalanx of thumb. (*Burrows.*)
B. Areas of cancellous destruction in terminal phalanges associated with bluish markings in nails. (*Dittrich.*)
C. Calcareous deposits around extremities of terminal phalanges. All the fingers and thumb were similarly affected.
D. Erosion of phalanges with gouty deposits.
E. Osteitis multiplex cystica.
F. General rarefaction of bone with areas of cancellous destruction due to carcinomatous deposits.
G. General rarefaction of bones with localised areas of destruction of cancellous bone with pseudo-fracture of the middle phalanx. (*Looser's umbauzonen.*)
H. "Hole" in metacarpal caused by injury to cancellous bone. (*Duncker.*)
I. Erosion and absorption of terminal phalanges as seen in leprosy, Raynaud's disease and scleroderma, and some cases of bronchiectasis.
J. Unusual dystrophy of metaphysis of terminal phalanx of little finger.
K. Erosion of terminal inter-phalangeal joint surfaces in a case of psoriasis.

graphs illustrating these appearances are to be found in the paper by *Muskat.*

The radiographic appearances in individual lesions of gout and rheumatoid arthritis may be very similar. Gout is more frequently asymmetrical and is usually associated

with a great toe lesion No bone changes may be detected in it for some years In Rheumatoid Arthritis the lesions associated with considerable osteoporosis are rapidly destructive, more extensive, usually bilateral and may involve every joint of the body eventually the joints may dislocate ankylose or develop the secondary degenerative changes of osteoarthritis.

Calcareous Deposits around the extremities of the terminal phalanges as in C, Fig 48 without any bone changes are seen in some cases of Raynaud's disease scleroderma and allied conditions They are dense deposits whereas sodium biurate crystals are transparent *Both may occur in gout.*

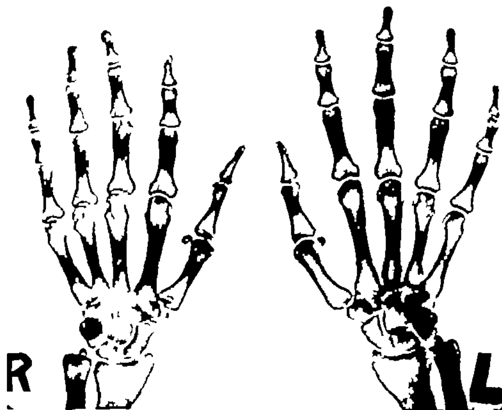


Fig 48A. Radiograph of Miss N W aged 39 showing condensation of the bones in the terminal phalanges of the middle ring and little fingers of both hands with osteoporosis of the third, fourth and fifth metacarpal and their phalanges of the right hand These features in the terminal phalanges indicate that the blood supply to the terminal phalanges has been restricted for some years while the osteoporosis of the bones of the *right hand indicat* additional neurovascular disturbance The patient was considered to have vaso-spasm acrocyanosis of both hands and feet Sclerodactyly developed in the right hand during the last three years Cervical stellate ganglionectomy was done on both sides the right not being successful

In Hyperparathyroidism and certain severe degrees of Type B Renal Rickets the terminal phalanges may be completely decalcified. On the other hand one sees occasionally the terminal phalanges with the cancellous tissue blotted out by dense condensation of bone This was well marked in a case of Idiopathic Steatorrhœa (Gee-Thayson's Disease). It occurs in some cases of Scleroderma and Raynaud's Disease It appears

to be emphasised when the cancellous extremities have decalcified after neurovascular disturbance (see Fig 48 A).

Osteoporosis of fourth and fifth metacarpals and all their associated phalanges was seen to develop in a man of 23 years who had sustained a blow on the ulnar nerve at the elbow No other changes

Associated with **Lupus Pernio** and *Boeck's* **Sarcoids**, small circular ovoid or irregular areas of cancellous destruction are shown on radiographs of the phalanges and metacarpals (see E, Fig 48) This appearance was first described by *Jungling* There is no definite atrophy of the adjacent bone but the cyst like cavities may so weaken the bone that pathological fractures may occur at the site The condition goes under the name of **Osteitis Tuberculosa Multiplex Cystica** and illustrations of the conditions are to be found in the papers of *Jungling Rückoldt Schaumann* and *Caudi* *Voorhoeve*[1] draws attention to the existence of a spinal affection in a typical case The lesions in the cord appeared to be related to the nerve supply of the involved bones and he puts forward the suggestion that these areas are due to trophic disturbances *Murdock* and *Hutter* draw attention to a somewhat similar appearance of the bones in leprosy which they name **Leprous Osteitis Multiplex Cystica**, but this disease is often associated with amputations or erosions of the extremities of the terminal phalanges (see I, Fig 48) and an irregularity of some of the interphalangeal joints suggesting chronic destructive osteitis; in the young patient his involvement of the growing bone leads to shortening of the particular phalanges. The degree of cutaneous leprous involvement is not a reliable index to the amount of bone pathology These writers also point out that the nutrient foramina are unduly prominent This feature I have found to occur also in association with **Granuloma Annular** *J Karaseff* who analysed the bone changes in 77 cases of Leprosy referred to small semicircular bony excrescences at the terminal phalanges and fine corrugations of the diaphyseal surface diffuse osteoporosis of the bones of the hands and feet with sharply defined semicircular defects in the radial aspect of the first and second phalanges which slowly increased in size but without accompanying periosteal changes solitary cysts in the metaphyseal region of the proximal phalanges of the hands and feet which may result in fracture More marked bony changes are seen in cases with severe neurotrophic disturbances Localised osteolysis of the radial aspect of the proximal phalanges of the index, middle and ring fingers occurs such as we see in some cases of Gout.

Hansen[2] has described three cases of a multiple form of circumscribed destruction of the bones of the hand. In the first two cases there were destructive areas also in the phalangeal bones of the foot and in the heads of the metatarsals. These areas are well defined, the cancellous lamellæ being completely absorbed. Tuberculosis, syphilis, gout and fibrous osteitis, he says, were completely ruled out. He calls it a multiplex circumscribed osteitis of origin unknown.

Erosions of the tufted extremity of the terminal phalanges in a mild degree is common in children. It appears to be associated with under feeding An extreme example is shown in Fig 25 It is present to a marked degree in some cases of **progeria**.

Irregular erosion or amputation of the extremities of the terminal phalanges (as in I, Fig 48) is also to be found in the hands of patients suffering from **Bronchiectasis**, ***Ainhum*** **Syphilis Thrombo-Angiitis Obliterans (Buerger's Disease), Raynaud's Disease Syringomyelia, Psoriasis, Diabetic Gangrene, Haematoporphyrinuria** and **Scleroderma** Radiographs illustrating such deformities in these diseases are to be found in the papers of *Boral Kornblum* and *Edeiken* In a paper on the bone changes in Leprosy *Hopkins* illustrates amputations of much greater severity involving even the upper thirds of the metacarpals

He says that the process is a very slow one taking 10 20 or 30 years before the phalanges are absorbed

Fig 49 shows the hands of a patient with syringomyelia in which slowly progressive destruction of the phalanges is occurring

H H Barber described the case of a man, aged 51 years, who developed keratoderma and fissures with ainhum like constrictions and a psoriasiform lesion *twenty years* before the development of syringomyelia with subsequent loss of the fingers on one hand.

An unusual but characteristic pathological change in the terminal phalanx is *shown in J Fig 48.* This is a drawing of a radiograph of the little finger of a girl aged

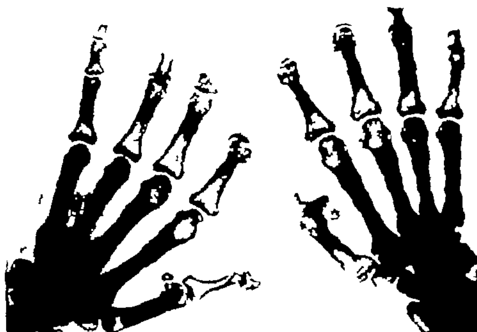


FIG. 49. Radiograph of hands of girl aged 23 showing progressive dissolution of the phalanges. Case of syringomyelia.

0 years, who for 12 months had noticed a swelling of the end of the finger The surgeon who examined the finger sent her for a radiograph with the provisional diagnosis of an enchondroma. There was no evidence of injury More recently I have seen a bilateral case in a boy aged 10 and a number of isolated cases *Kirner* has illustrated an identical bilateral condition in a girl of 10 *A R Thomas* described this bilateral deformity in girls aged 8, 11 and 12 years. Though in recent years quite a large number of the lesions have been seen, their aetiology has not yet been established.

Fig 48F is a line drawing of a radiograph from a case of Carcinomatosis of Bone. It shows a general rarefaction with areas of destruction of the cancellous reticulation due to small carcinomatous deposits As a rule the diagnosis would have been known from other lesions, but occasionally no primary tumour has been suspected or found and one radiographs the hand of the patient who has had an injury and discovers such evidence

Osteomalacia is associated with marked osteoporosis of the bones, and while the effect of this is mostly seen in the pelvis and bones of the lower extremity radiographs

of the hands will sometimes show the general features of the disease as in Fig 48 The linear defect in the middle phalanx is considered by *Looser*[8] to be an end result of a rebuilding process and not a fracture These pseudo fractures are frequently found in **Osteomalacia** and occasionally in **Rickets** and **Osteitis Deformans** They show on the radiograph as a central zone of unossified tissue which extends transversely across part or the whole of the shaft This area of rarefaction is bounded on either side by an area of relative density compared to the other bone of the shaft These defects are usually

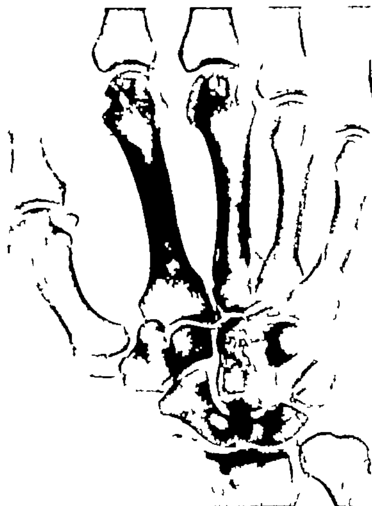


FIG 50 Radiograph showing cyst-like changes in the heads of the second and third metacarpals, the os magnum scaphoid and unciform of a man who had worked for 10 years with a compressed air drill.

multiple and often symmetrical which is against them being traumatic in origin (see *Milkman*, also *Michaelis* for illustrations)

It is unusual to associate a hole in a long bone with an injury which has not involved the use of a sharp instrument, but occasionally this appearance is recorded, as in H, Fig 48 details of which are given by *Duncker* in his paper

The author has radiographed the hands of a number of men after they had been working with compressed-air drills in road making etc., for more than 10 years. The

radiographs of all these men show small circumscribed areas of cancellous destruction in the heads of the metacarpals and the carpal bones, but no evidence of irregularity of the articular surfaces as in arthritis (see Fig 50) These areas resemble the cyst like



Fig 51 Idiopathic steatorrhœa. Characteristic features. No compact bone

formations which are frequently associated with severe trauma to the carpal scaphoid, and it is probable that they arise from absorption due to hæmorrhage following injury to the cancellous bone The formation of these small bone "cysts" in injured cancellous structures serve to support the theory that trauma is the cause of the bone cysts seen in the shaft of the humerus, the neck of the femur or the lower end of the radius.

Isolated or multiple well-defined areas of cancellous destruction are seen in the metacarpal extremities and in the carpal bones. In some cases but a thin shell of cortex remains. *There may be no sign of reaction in the articular surfaces of the bones.* The ætiology of these lesions has not been determined. Trauma does not appear to be the essential factor. Such cyst-like excavations are found in gout and in the neighbourhood of rheumatoid and osteoarthritic joints.

The radiographic appearances of the hand and other bones of the skeleton are characteristic in well-marked cases of **Idiopathic Steatorrhœa** (see *Fig. 51*). The periphery of the bones is regular and clearly defined but there is no compact tissue and the cancellous structure is more open; consequently the bones are less dense (see p. 60).



FIG. 52. Radiograph *of the* hand *of a girl* aged 10 *years showing dense epiphyses to the* terminal phalanges of all the fingers with the exception of the ring finger, which is normal in density and structure. Two years after this radiograph was taken a further X-ray examination revealed that the epiphyses of the terminal phalanges had fused with the diaphyses and had lost their density and were indistinguishable from the normal. The epiphyses for the other phalanges had not yet fused. Compare with Figs. 21 and 53.

Platt illustrates a number of conditions producing cystic changes in the bones of the hand and foot, including **Fibro-cystic Disease of Bone**, **Myxochondroma**, **Chondroma** and **Giant-cell Tumours**.

Dense Epiphyses. A very unusual appearance of the epiphyses is shown in *Fig. 52*, which is the radiograph of a girl aged 10 years. This radiograph was taken along with radiographs of the entire skeleton because there was absence of cancellous bone structure in the vertebral bodies which showed apparent density of upper and lower borders. No explanation could be obtained as to the nature of the condition. The epiphyses for the terminal phalanges of all the fingers, with the exception of the right ring finger, consist

radiographs of all these men show small circumscribed areas of cancellous destruction in the heads of the metacarpals and the carpal bones, but no evidence of irregularity of the articular surfaces as in arthritis (see Fig 50) These areas resemble the cyst like



FIG. 51 Idiopathic steatorrhea Characteristic features. No compact bone.

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of very dense bone in which it is impossible to see any structure. The contrast with the epiphyses of the terminal phalanges of the thumbs and that for the ring finger is remarkable. As stated in the legend two years later the dense terminal epiphyses had fused and lost their abnormal density. Such dense epiphyses are sometimes involved in trauma and the mistake has been made by certain authors regarding such epiphyses as examples of avascular necrosis. Radiography of the whole of one or both hands may reveal similar density in one or more of the epiphyses. That there is some excuse for this is illustrated in Fig 53, but the antero-posterior radiograph of this hand showed also a dense epiphysis to the terminal phalanx of the little finger which had not been injured. An account of an unusual dystrophy was published by the author (see Fig 21) in which all the epiphyses were laid down in this dense bone which was gradually replaced by normal bone before or after fusion with the diaphysis



FIG. 53. Displaced diaphysis with dense epiphysis. The latter developmental and not due to avascular necrosis (see Fig 33).



FIG 54 Radiograph of fusiform expansion of middle finger showing compression and fragmentation of epiphysis at base of middle phalanx and erosion of head of proximal phalanx. Note also the relative density of the other epiphyses. Bilateral Boy aged 13 years. No history of injury gradual onset Thiemann's disease

Osteochondritis of the Phalanges of the Fingers. *Thiemann* in 1909 described a pathological condition of the phalanges associated with fusiform swelling of the proximal inter-phalangeal joint and changes in the epiphyseal cartilage in late childhood and during puberty. Other observers notably *Esau Dale Klober Weil Dessecker and Fleischner* have described similar cases. *Reinberg* and *Grasiansky* have given a good account of 6 cases which they called Multiple Osteochondropathy of the Phalanges of the Fingers. One such case has been submitted by *Davidson* to the author (see Fig 54)

A review of the cases described with their radiographs permit of the following general description. The condition is more commonly found in the proximal interphalangeal joint of the middle finger of both hands but a good proportion of the cases showed the second, third and fourth fingers were similarly affected. Occasionally the fifth also

No indication of endocrine or constitutional anomalies or pathology is indicated

elsewhere by clinical biochemical or radiographic examination It occurs in both sexes but more commonly in the male during the age period 14–20 years The onset is usually insidious though there may be history of trauma and according to the latter two authors, usually a history of exposure of the hands to cold

Fusiform swelling of the proximal interphalangeal joint associated with some restriction of movement and pain during work and fatigue or on pressure or on exposure to cold No skin changes are present as a rule Later the affected finger may appear to be stunted and if several are affected slight radial deviation of the fourth and fifth and slight ulnar deviation of the first and second fingers may be noted (the opposite to the deviation we see in achondroplasia)

Radiographically the lesions are typical they exhibit the sequence of changes seen in osteochondritis in other sites *i.e.*, **Legg-Perthes's Disease of the Hip Joint and Köhler s Disease** of the second metatarsal head. These radiographic indications of avascular necrosis with concomitant reaction in neighbouring bone are confirmed by the observations of *Dessecker* on the histological appearances of material examined by him. The involved finger shows an increased density of the basal epiphysis of the middle phalanx later this may show fragmentation and compression beyond the normal confines of the epiphyses. Reactive changes in the base of the diaphysis are indicated by osteoporosis and plasticity leading to a certain amount of splaying out Small cyst like areas of decalcification may be present

The joint space shows no marked changes apart from irregularity of its boundaries. The metaphyseal borders are irregular but the growth cartilage appears unaltered: fusion of the epiphysis and diaphysis is unaffected, it occurs at the same time as the unaffected phalanges. Irregularity of the articular surface of the head of the adjacent proximal phalanx may be produced Some apparent increase in the densities of the epiphyses of the other phalanges may occur as in Fig 34 The dense islands of the involved epiphyses are gradually decalcified, finally re-ossification occurs in the extremities if compression has occurred in the plastic stage this is permanently consolidated.

Differential Diagnosis The bilateral lesions of the base of the middle phalanges which I found in the youth of 17 (see p 34 Fig 47) bear some resemblance The proximal inter-phalangeal joint of the middle finger is often subjected to greater trauma than we might expect. Damage to this joint with resultant fusiform expansion has persisted for twenty years in the middle finger of the author s right hand following a stubbed golf shot out of the rough. The lesions due to definite trauma do not usually show the sequence of changes seen in osteochondritis.

The condition which I have described as **Peripheral Dysostosis** (see p 28 Fig 20) is one which is frequently mistaken and described as **Thiemann s Disease** for in that dysostosis disturbances on both sides of the growth cartilage leads to stunted fingers but with rather more marked deviation. It is not associated with pain and is discovered at an earlier age Its resemblance to the changes seen in cranio-cleido-dysostosis and its association in well-marked cases with changes in the more proximal bones indicates its developmental character

The phalanges in **Kaschin-Beck s Endemic Disease** show somewhat similar changes to those of the dysostoses rather than those of osteochondritis It also involves the basal phalanges the first metacarpal and the carpal elements and the vertebral bodies

The osteo-dystrophic changes shown in Fig 40 may be mistaken for osteochondritis Many joints of the body of this patient showed similar lesions

Tuberculosis syphilis osteomyelitis gout rheumatism and various endocrine disturbances may produce localised fusiform swellings of the interphalangeal joints which

may suggest this condition of osteochondritis, but radiographic examination will permit of differentiation.

Osteochondritis of the Metacarpals. The heads of the second and third metacarpal in particular are the site of localised avascular necrosis with its surrounding osteochondritic reaction. The radiographs show the same sequence of changes as is recorded in other sites, *e.g.*, Köhler's Disease of the second metatarsal.

Destruction of the Epiphyses by Freezing *R B Bennett* and *W P Blount* recorded that a girl aged 8 had frozen all the fingers of the left hand in December 1931 with subsequent loss of the finger nails Swelling appeared in June, 1932—swelling of the proximal inter-phalangeal joints of digits two, three and four with crepitation and some limitation of movement. The third and fourth digits were crooked with the apex of the angle medially and at the proximal interphalangeal joint. The radiographs showed slight generalised bone atrophy The epiphyses of the first digit, the outer four metacarpals and the proximal phalanges were otherwise normal the epiphysis at the proximal end of the fifth middle phalanx was also normal. Those of the distal phalanges of the second, third, fourth and fifth digits, as well as the middle phalanges of the second, third and fourth digits, were entirely absent. The metaphyses at these joints were markedly irregular in contour and appeared moth-eaten.

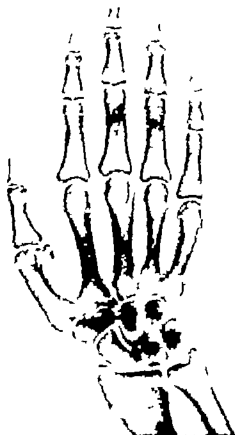


Fig 33. Hypertrophic pulmonary osteoarthropathy (Pierre Marie-Bamberger disease).

PERIOSTITIS

Rheumatic Periostitis *P A Tepper* and *G E Harpekov* have called attention to localised periosteal thickening of the phalanges (chiefly the proximal phalanges) and the metacarpals in cases of rheumatism.

The characteristics of rheumatic periostitis are a tendency to regeneration, recurrence and a general reaction expressed by a rise in temperature and an increase in the erythrocyte sedimentation rate The periosteal reaction may take 18 days to appear after an acute attack and 4 months to disappear

Clubbing of the Fingers. In association with various pathological conditions of the lungs, notably abscess bronchiectasis chronic tuberculosis and certain pneumonokonioses and primary and secondary neoplasms as well as in uncompensated cardiac defects, the digital extremities show marked curvature and expansion Radiographs of the hands in such cases may reveal no bone changes even when the clubbing is most marked In some cases of bronchiectasis erosion of the periphery of the cancellous tuft of the terminal phalanges may be marked (see Fig 48 I) but no other bone changes may be present. In certain cases the condition of Hypertrophic Pulmonary Osteoarthropathy

(Pierre-Marie-Bamberger's Disease) develops. Though this is frequently associated with pulmonary disease it has been recorded with chronic infections of the alimentary canal, sprue, chronic diarrhœa and biliary cirrhosis. Simple clubbing or this bony manifestation has been found in patients in whom no concomitant pulmonary or other lesions could be detected. In some of the latter cases further radiography at a later date has revealed the development of primary or secondary neoplasm in the lungs. The condition is associated with œdema of the extremities which may not pit on pressure The extremities may appear to be congested particularly around the nail bed. The condition may be found at all ages It has been seen in association with pulmonary disease, inflammatory and neoplastic, in the early months of infancy and in old age Effective treatment of the pulmonary lesion has led to the disappearance of the bone changes. The rapidity of development of the bone changes differs—in some cases it appears to develop within a month or so of the pulmonary lesion, in others development is insidious, but even so its demonstration may precede the detection of radiographic changes in the lungs. In others it may develop as a terminal phenomenon at the end of a long illness (see Fig 53)

Histological examination of the periosteal new bone has usually not revealed any neoplastic infiltration, but in certain cases neoplastic infiltration has been reported. It does not accompany all chronic inflammatory or neoplastic diseases of the lungs. What decides its appearance is not known.

Radiographs show irregular periosteal accretions of new bone along the shafts of the bones and around the periphery of the larger bones of the pelvis and shoulder girdles The periosteal involucrum of bone appears to diminish in thickness with the size of the bone, being thickest in the femur and least in the middle phalanges. The terminal phalanges do not usually show any reaction though in certain cases some irregularity of the terminal cancellous tuft is seen. No irregularity of the articular extremities or of the periphery of the carpal bones is shown

The involucrum is usually much less dense than the cortex though all the bones exhibit some degree of osteoporosis. Its surface is usually irregular and sometimes woolly in outline. It may be thicker over the posterior surface than the anterior In one case seen by the author a youth of 18 years, the periosteal new bone was laid down in regular concentric laminations of bone of normal cancellous density within it the normal compact cortex appeared to be incorporated all the long bones with the exception of the terminal phalanges acquiring a thickness nearly double that of the normal. No pulmonary lesion was detected

Accounts of cases have been published by *Odessky* and *Sheraknev Kennedy Miller Roy* and *Jutras* and *Martin*

The case recorded by *E Freund* had more extensive lesions without any sign of pulmonary disease.

In the case of hæmangioma of the hand and arm (see Fig 46) and the erosions of the terminal phalanges (see Fig 23), clubbing of the fingers was present.

ARTHRITIS

Heberden's Nodes. *Heberden* in his account of digitorum nodi described "little hard knobs about the size of a small pea which are frequently seen upon the fingers particularly a little below the top near the joint." They appear as two small bosses on the dorso-lateral borders of the distal interphalangeal joint. They occur in both sexes more commonly in females and after the age of 50 They are of a degenerative and not of a gouty nature though in themselves not painful or disabling are later associated with Osteoarthritic Changes in the terminal interphalangeal joint (and

proximal joint in some cases) which may be both painful and disabling. Trauma of industry (*e.g.*, tailors and seamstresses are affected) which necessitates constant function



Fig. 50. Osteoarthritis of interphalangeal joints associated with Heberden's nodes.



Fig. 51. Still's disease in infant aged 2. Note periarticular swellings and absorption of cancellous structure in carpal bones.

of the terminal joint appears to be a factor in the development. At the beginning the nodes are soft and do not restrict movement but if associated with definite trauma they may be painful, indicating the need for temporary immobilisation. The lesions appear to be associated with proliferation of cartilage at the joint margins; later this undergoes ossification in association with atrophy of the articular cartilage, erosion and splaying out of the approximated bony surfaces. Though only one finger may show the nodes at the earlier age ultimately the other terminal joints are involved. *The index, middle and ring fingers are most* commonly affected. Even with complete destruction of several joints the patient may have little discomfort unless injured or fatigued (see Fig. 50).

Polyarthritis Chronica Juvenilis (Still's Disease). In the infant fusiform swellings over the joints of the fingers, particularly of the proximal interphalangeal joints of the index, *middle and ring fingers, are usually associated* with atrophy of the bones, but without any irregularity of the joint surfaces. Marked swelling around the wrist is often associated with irregularity of outlines of the carpal elements, particularly the more recently ossified. The cancellous structure of their interiors may be wholly or partly destroyed. The larger joints

of the body may show irregularity of the joint surface and dislocation of the hi
may occur (see Fig 57)

Rheumatoid Arthritis. In the early stages of acute arthritis the radiograp
only soft tissue swellings as in Fig 58. In others this is later associated wit
destructive changes as in Fig 59 Multiple arthritic changes are seen in th



Fig. 58 Acute interphalangeal arthritis. Soft tissue swellings. Little bone change



Fig 59 Destructive interp arthritis.

phalangeal and carpal joints. The bones show general atrophy and osteoporo
articular extremities of the bones show changes of varying severity In the less
joints the only change may be a diminution in the joint space others show sn
of cortical erosion of the medial or lateral aspects of the articular surface, pa
of the heads of the phalanges and metacarpals not on the central articula
as in osteoarthritis The joint surfaces may later be fused—a common findi
carpus—or the phalanges may be subluxated or dislocated with or without de
of the ends of the bones (see Fig 60) Large areas of cancellous destruction m
cyst like appearance to one or more of the bones (see p 603)

Gonorrhoeal Arthritis. In this condition the bones of the hand show
rarefaction the articular surfaces of the involved joints lose their distinct ou
now appear to be blurred Fusion of the articular ends may occur If the
located in the wrist a marked osteoporosis of the bones of the hand usually occ

joint irregularity or reduction of joint space Small periosteal bosses may be shown in certain bones suggesting that the affection primarily involves muscular attachments. It must be appreciated that such sequence may occur in the large joints and be associated with clinical signs out of all proportion to the trifling bone changes. Slowly progressive painless destruction of several or all of the terminal interphalangeal joint surfaces of the



FIG. 60 Radiograph showing the destructive changes of rheumatoid arthritis. The proximal interphalangeal joint surfaces of the little finger and the articular surface of the head of the fifth metacarpal are destroyed and there is subluxation of the little finger Similar changes are shown in the heads of the third and fourth metacarpals and the interphalangeal joint of the thumb. All the bones show osteoporosis.

fingers and toes may be found in adults who are affected with recurrent psoriasis. These lesions progress and the more proximal joints, even the wrists, may be completely destroyed in association with considerable atrophy and dissolution of the bones. The hands and feet may come to resemble radiographically the feet of a bird H *Shlionsky* and *F G Blake* have published photographs and radiographs of a case showing pronounced destruction and deformity (see Fig 48, K)

Osteoarthritis Deformans Endemica. In 1861 *Kaschin* described an endemic poly arthritis which occurred in the Urow valley of the Transbaikal. *Beck* subsequently called

it osteoarthritis deformans endemica," and stated that in his opinion it was due to drinking the water of the river. It begins in early childhood and progresses into adult life. Little or no pain may be associated with it. The joints of the hands and feet show a symmetrical progressive arthritis producing a clinical appearance resembling chronic gout. Later the knees, shoulder and most joints of the body may be involved to some degree.

Involvement of the growing bones results in stunting of the long bones. *Schipatschou* considered that the condition was a complicated avitaminosis, which might be caused by eating unripe wheat.

Goldstein and *Nikiforov* describe three cases which occurred in the region of Mari (away from the Transbaikal)—a father aged 49 and two sons 15 and 8½ years—suggesting a familial condition. The radiographs show thickening and shortening of the phalanges with osteoporosis and joint deformities involving most of the skeleton. *Grazlansky* has recorded changes in the phalanges rather resembling those seen in the dysostoses, also pressure deformities of carpus, tarsus and vertebral bodies as in chondro-osteo-dystrophy.

Gout. The radiographic appearances differ not only in different individuals but in different joints of the same individual. The prominent feature clinically may be a marked swelling in the soft tissues in the neighbourhood of a joint. On the radiograph the swelling will be seen as a fairly well-defined rounded collection of homogeneous material about one of the phalangeal joints. The joint surface itself may appear to be intact, the only change in the adjacent bone being small discrete areas of cancellous destruction—such changes may be present in the bones of the fingers which present no clinical signs. Small sharply cut excavations may be seen on the lateral or medial aspect of the head, neck or base of the phalangeal extremities entering into the joint. In some cases the joint surfaces will be completely destroyed and small flakes of bone may be shown in the adjacent soft tissues, while in other cases larger rounded areas of cancellous destruction will be seen in the articular bone. In the chronic case which has been subjected to multiple attacks the fingers are shortened, thickened and deformed by periarticular gouty deposits and reactive changes in the soft tissues. Similar appearances are seen in Kaschin Beck's Disease. A few of the joints may be destroyed and a number of the bones show punched-out areas in the cortex or medulla. All of the terminal interphalangeal joints may be destroyed, the opposing bones showing multiple osteophytic outgrowths with little or no evidence of cancellous or compact destruction. In the intervals between the attacks there may be little or no pain, but with a multiplicity of damaged joints the chief complaint may be an increased weakness of grip (see Fig. 61).



FIG. 61. Cyst-like erosion of phalanges and metacarpal heads with destruction of adjacent joints. Compare with Fig. 141 which shows deposits in soft periarticular tissues. Note that there is not the general osteoporosis, dislocations or fusions as in rheumatoid arthritis. Gout.

Charcot's Joints. The radiographic appearances of neurotrophic joints of the hand

suggest a marked destructive arthritis. The joint space—the distance between the opposing surfaces of the phalanges—is increased, the bone ends are eroded and there is often a collection of ill-defined deposits of calcium in the tissues around the joint. This may be found in **Syringomyelia, Syphilis and Leprosy**. Similar appearances also occur in arthritis of the interphalangeal joints associated with **Psoriasis**. Illustrations are to be found in the papers by *Ström*, *Rocklin* and *Schirmunsky*.

Osteitis of the Phalanges may result from infection from without or within. The only change seen in the radiographs in the early stage may be an apparent solution of the cancellous trabeculæ of the shaft, the phalanx appearing to be constructed of a shell of compact bone. Later a thin line along the shaft of the bone (which is now of less density) may appear, indicative of periosteal involvement; ultimately the radiograph may show a fluffy ill-defined but expanded periphery outside the discernible normal shaft outline. Similar appearances are met with in all the tubular bones of some patients suffering from chronic inflammatory conditions of the lungs, hypertrophic pulmonary osteoarthropathy (*Pierre Marie* and *Bamberger*) (see Fig. 55).

Krause has recorded osteitis with periostitis of the middle phalanges following typhoid fever, and destructive arthritic changes have been noted in smallpox.

General osteoporosis with localised erosion of the cortex near the growth cartilage of the metacarpals and proximal phalanges is seen in some cases of leukæmia.

Periosteal thickening in the phalanges and metacarpals in **Lymphatic Leukæmia** is illustrated by *H. K. Taylor*, while *R. G. Taylor* and *Carter* have illustrated similar changes in the phalanges and metacarpals in **Coccidiodal Granuloma**.

Destructive changes as in osteitis with stunting of affected bones occur in the first metacarpal in **Progressive Myositis Ossificans**. The presence of this appearance in the radiograph may be of considerable help in assessing the gravity of a case showing myositis ossificans (see Fig. 18).

The development of osteitis in one of the phalanges of the hand may be the first manifestation of **Syphilis**. The radiographic appearances in syphilis are variable (see pp. 620–6). In the adolescent the development of osteitis of a phalanx without any evidence of superficial infection or trauma may give rise to the suspicion of **Sarcoma**, and the woolly outline of the reacting periosteum may be interpreted as supporting this diagnosis. If a careful correlation of the clinical and radiographic appearances is made, it should be readily possible to differentiate between them.

The same exercise of judgment has to be made in children presenting a tumour apparently involving one of the long bones of the hand. The patient or parents suggest that the tumour is increasing in size but there may be no tenderness on palpation. The radiograph shows irregular new bone formation, which in the early stages may present an ill-defined periphery around the shaft of one of the bones. The patient cannot remember a definite trauma, and on these findings the diagnosis of sarcoma has been made, whereas the radiographic picture is that of a fracture associated with much callus formation. The radiographic appearance of old inflammatory changes in the bones may be misleading. In one case seen by the author the patient sustained a gun-shot wound of the hand in 1916. After some weeks it healed and remained apparently well until 1938, when it began to swell. Radiographs showed irregularity of the second and third metacarpals, the result of infected fractures, together with a few metallic particles. There was no evidence of recent pathological changes in the bones, though clinically the appearance of the swelling suggested sarcoma, which it was proved to be. This is an instance of the latent negative radiographic period *overlapping the retained positive* radiographic signs of an old lesion. The differential appearances of these lesions are dealt with in the chapters dealing with periostitis and sarcoma.

Tuberculous Dactylitis. The radiographs may show any one of four different types of change

(1) A swelling often large and fusiform in shape is confined to the soft tissues with no apparent change in any of the bones or joints This may resolve completely (Fig 6* A)

(*) At first a periostal reaction suggesting a simple periostitis indicated by a linear deposit of new bone running along part or the whole of the diaphysis This gradually increases in thickness and expands. The normal shaft may be seen within the expanded periosteal sheath of new bone Gradually the structure of the original shaft is destroyed and the involucrum thickened. *During this time denser stippling of one or more areas*



Fig 62A. Tuberculous dactylitis Swelling of soft tissues. No bone destruction.



Fig 62B. Radiograph showing tuberculous spina ventosa of the fourth metacarpal bone

may be seen, so that the involved phalanx or other bone particularly in the infant, may appear to be twice its normal thickness of greater density than the other bone stippled and without normal cancellous trabeculæ. Much of the internal contents of the involucrum may be absorbed so that it now appears to be ballooned, the so-called **Spina Ventosa** (see Fig 62, B) Small areas of the involucrum may be destroyed. The whole bone may be completely restored and become indistinguishable from normal In other cases much of the affected bone is restored, leaving but one small, fairly well-defined area of destruction. This may persist for * or more years as a chronic lesion the surrounding bone shows sclerosis Destruction of the growth cartilage and invasion of the epiphysis usually results in stunted growth of the affected bone and occasionally the joint is involved and destroyed.

(3) The affected phalanx appears to have been infiltrated by the organism. The finer cancellous structure and the compact cortex are absorbed leaving a coarser cancellous

model of the bone which may show some expansion. This may be restored to normal. Fracture of the weakened bone may occur in the active phase and deformity result (Fig 62, C).

(4) The affected phalanx shows but a small defined area of cortical or cancellous destruction often near and involving the joint, but with no apparent change in the other part of the bone or its neighbours. Later osteoporosis of all the other bones may show up against the lesion which by now may have attracted calcium and appear denser. Deformity of the affected finger is certain. The lesion may persist in a chronic form (see Fig 62 D).

As indicated in the description of type 1 though there may be obvious clinical signs of

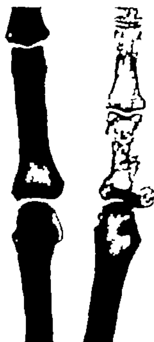


FIG. 62C. Tuberculous dactylitis. Honeycombing of proximal phalanx which has fractured.



FIG. 62D. Chronic tuberculous osteomyelitis of second metacarpal

disease, the bones, at any rate in the early stages, may show no apparent radiographic change from the normal. Later usually within a month, the definition of the bone at the focus becomes very apparent particularly at the extremities, which, for a time, show a marked contrast to the shafts—the latter then appear to have an added density but later general osteoporosis of a profound degree is characteristic. If the focus is located in a finger all its phalanges and corresponding metacarpal (as in Fig 62, C) may show so great a degree of osteoporosis in contrast to the other phalanges and metacarpals that the extent of the focus in the finger may be difficult to determine on the radiographic evidence.

Similar appearances have been recorded in Syphilis (*Gaucher* and *Giroux*), Coccidiodol Granuloma (*Taylor*)

Vogt[1] noted Dactylitis in 16 per cent of 104 cases of congenital syphilis. Enchondromata and myxomata occurring singly sometimes produce a localised or generalised expansion of the phalanx or metacarpal and simulate spina ventosa.

Angioma of the bone and diffuse infiltration of the bone by chondromatous cell may produce radiographic appearances simulating *tuberculosis type 3, but evidence of*

angioma in the soft tissues may be apparent on clinical examination and the radiographs may show the changes illustrated in Fig 40 or the typical appearance of phleboliths, whereas in the latter more typical chondromata may be shown in the larger bones (see also Kast's disease p. 52 and Fig 42, F).

Generalised diseases of the skeleton e.g. Rickets, Scurvy Albers-Schönberg's disease Osteopoikilosis and Hyperparathyroidism produce their characteristic radiographic appearances in the bones of the hand as elsewhere.

In the condition of polyostotic fibrous dysplasia all bones of the skeleton may be involved as in Fig 63 or the dysplasia may be manifested in isolated bones as in Fig 64

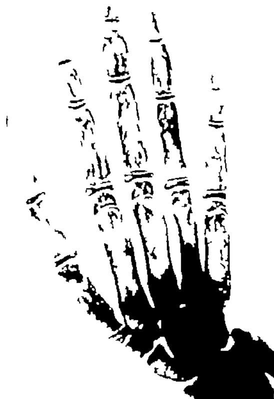


Fig 63. Polyostotic fibrous dysplasia, boy aged 14 years. All the bones in the skeleton of this boy were changed.

Certain diseases of the skeleton, which, though spoken of as generalised because of the multiplicity of sites sometimes involved may not affect any or all of the bones of the hands When but one phalanx, metacarpal or carpal bone is affected in a patient in which the disease has not been suspected its appearance may confuse Further radiography of the skeleton may help in the diagnosis Perhaps the most confusing of these are Paget's Disease, Leukaemia and Carcinomatosis. An example of this is shown in Fig 65 which is the radiograph of a man aged 64 who in 1938 was radiographed to ascertain evidence of the cause of a swelling in the wrist The fifth metacarpal was seen to be uniformly dense and compared with its fellow in the opposite hand was slightly longer and thicker Radiographs of the skeleton showed similar changes in the astragalus

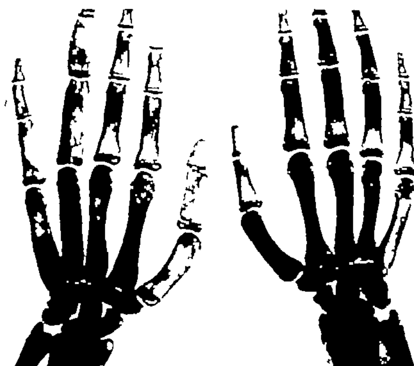


Fig. 64. Polyostotic fibrous dysplasia of isolated bones of left hand (see p. 371).



Fig. 65. Dense fifth metacarpal. Paget disease. It gave no clinical signs during the 5 years it was under observation. Patient aged 64.

of both feet the sesamoids of the right big toe the whole of the left tibia and of a localised area of the sphenoidal bone

I have watched this case regularly for 5 years but at no time has there been any clinical evidence of these lesions The fifth metacarpal can be easily palpated and appears to patient and examiner as quite normal During the first 2 years of observation the lesions in the astragalus showed very definite resolution towards the normal but this has not continued I regard it as an example of the osteoplastic type of Paget s disease

I have seen several examples of such dense phalanges in which fracture has occurred —Paget bone has less elasticity than the normal In one case the lesion, because it showed increased density had been regarded as secondary carcinoma from a malignant prostate Isolated lesions of such conditions as melorheostosis may also create difficulties in diagnosis.

Progressive Osteolysis of the Bones of the Hand. *J Dupas J Badelon* and *G Gayde* report the case of a youth aged 17 years who in perfect health sustained a fracture of the second metacarpal bone; this bone gradually disappeared A bone graft from

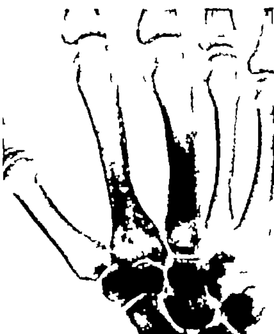


Fig 66A. Case of rly sarcoma. Radiograph of the hand of a youth aged 21 14/12/32. Provisional diagnosis from clinical examination. Recent fracture on top of old fracture of the metacarpals. Not the surface irregularity of the shaft of the second and third metacarpal at the st indicated.



Fig 66B Radiograph of same hand as Fig 66A, 14/2/33, bowing marked increase in the size of the tumour of soft tissues with periosteal new bone on the outer side of the second metacarpal Biopsy—Fibrosarcoma.

the tibia was inserted but this was absorbed. Later a fracture of the third metacarpal occurred. Serial radiographs taken during the following two years showed almost complete osteolysis of the first, second and fifth metacarpal bones and the proximal phalanx of the index finger Ultimately complete autolysis of all carpal bones occurred A further report indicates that the autolysis still progressed and had involved most of the remaining phalanges Sympathectomy ultra violet irradiation and other forms of

treatment had no effect. No other abnormality could be detected on clinical, blood or biochemical and complete radiographic examination.

More recently a similar progressive attenuation and dissolution of the metacarpals beginning in the third in a patient in whom no explanation for its cause could be obtained in any way has been recorded by *W A Jackman* The third metatarsal shaft appeared to be slowly concentrically absorbed. Its outline was preserved regular as if it had been turned down in a lathe.

Under the title "Une Variété rare de Rhumatisme Chronique La Main en Lorgnette" *Marie* and *Leri* in 1013 described a destructive polyarthritis in a woman of 70 years of age. It was of many years duration and had produced telescopic deformity of the fingers by destruction of the metacarpo-phalangeal and interphalangeal joints. In previous editions the author drew attention to a similar case recorded by *Cohen*. More recently *Nielsen* and *Snorrason* under the name Arthritis Mutilans have reviewed some published cases and given an account of 6 cases. These were women past middle age who had suffered from polyarthritis for many years. They presented no evidence of psoriasis or nervous complaint. The affected fingers and toes were short and tapering from a stout base. The joints were loose. Radiographically the metacarpal heads were worn conical and the bases of the proximal phalanges were expanded and markedly excavated. The proximal phalanges were shortened by considerable erosion of their heads and this was associated with much destruction of the bases of the middle phalanges The distal interphalangeal joints were unaffected The feet may be similarly affected. All or only one or two of the digits may be similarly affected. The condition appears to be distinctive but its aetiology has not been determined the appearances suggest that it begins as in Fig 59 and is followed by a slowly progressive "disuse" atrophy of the affected bones.

Tumours of the Bones of the Hand. Apart from chondromata myxomata osteomata and hæmangiomata which have already been described, examples of most of the other bone tumours have been published, including giant-cell tumours and various types of sarcoma, the radiographic features of which have been described in other chapters.

Radiographs of a periosteal fibro-sarcoma are shown in Figs. 66 A and B and an account of another which arose at the seat of a gunshot wound 20 years old is given on p 70

An interesting example of a giant-celled tumour of the terminal phalanx of the finger is given by *Elmslie*

CHAPTER III

THE CARPUS

Mention has been made in the last chapter of the order of the radiographic appearance of ossific nuceli of the carpal bones. By comparing the degree of ossification of the carpal and tarsal nuclei *Flory* has attempted to judge the age *Köhler* finds that ossification of the carpal nuclei is more forward in the children of the well to-do than in the children of the working classes. Ossification is delayed in Mongolism, Myxœdema and certain Endocrine Deficiency Disorders (see page 20-8).

The nuclei are irregular and sometimes multiple in Chondro-osteo-dystrophy

Many supernumerary carpal bones have been described the knowledge of which may guard one against error in interpreting the radiographic appearances of the carpals

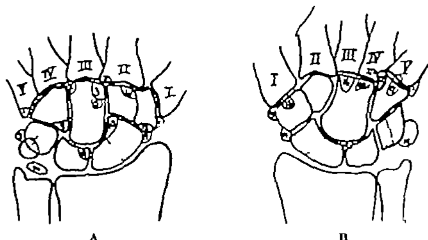


Fig 67

following injury Radiographs taken within a day or so of the injury may present little difficulty but the presence of accessory bones in the radiographs taken two or three months after the injury may require very careful consideration, for fragments which have been separated from bones in the neighbourhood of joints, particularly the wrist and mid tarsal joints, frequently fail to unite with time their margins are rounded off and in some cases develop an articular facet features which may cause them to be regarded as accessory bones. The safest plan is to radiograph the opposite side for though occasionally unilateral differences are present, as a rule ossification is symmetrical.

Fig 67 A and B are drawings showing the position of the accessory bones of the carpus which have been described by *Pfitzner* and others. The reader seeking information on these accessory bones is referred to the works of *Köhler Grumbach* and *Crashey*

FRACTURES

The size of the book will not permit me to deal with the radiographic features of the common fractures—most of them are illustrated in books on surgery but certain fractures occur which require very careful scrutiny of the radiographs taken in several planes, and even when this has been done a guarded opinion may have to be given

As an example the details of the following case are given.

A youth met with an accident to the wrist by falling. The clinical features suggested the possibility of a fracture in the neighbourhood of the ulnar styloid, and to show this, a radiograph was made on 14/12/32. A careful examination of this radiograph gave no indication of bone injury. As the patient continued to have pain in the wrist, he came for a further radiographic examination—31/1/33. This radiograph shows a cyst-like condition in the middle of the scaphoid with a fracture line running through it—due undoubtedly to the injury for which he was first radiographed.

The explanation for these conflicting appearances is that the injury resulted in fracture of the cancellous bone without any alteration in the contour of the bone. The fracture is masked by the shadows of the cancellous trabeculations being superimposed upon one another in the radiograph.

As a result of the fracture, hæmorrhage or leakage of synovial fluid into the damaged area occurs and later the hæmorrhage results in exudation of serous fluid into the area. This increase of pressure in the bony shell causes absorption of the cancellous bone and a cyst-like cavity is formed. The pressure in the cyst may separate the fragments so that a radiograph will now disclose a fracture line if the periphery has been involved, as in the case cited, but if this has not occurred no fracture line may be seen.

Cyst-like Changes in Carpal Bones. It is conceivable that in some cases of fracture only a rupture of some cancellous trabeculæ occurs and the resulting internal hæmorrhage leads to absorption of cancellous bone which weakens the bone, and it fractures during an injury not severe enough to attract the patient's attention. I have found similar cyst-like changes in the heads of the metacarpals and in all the carpal bones of men working with compressed air drills (see Fig. 50). *Weiss* has shown that these changes occur with such frequency in riveters as to suggest that its demonstration should constitute evidence of a claim under the Workmen's Compensation Acts.

The cancellous tissue in one or more of the carpal bones may be completely absorbed leaving only a thin cortical shell of bone. Such lesions may be associated with sharply defined localised areas of cancellous destruction in the near ends of the metacarpals, radius and ulna, or with irregularities indicating old injury. One or more of the carpal bones may show complete disintegration of the contents and have but a thin shell of bone, yet for years the wrist (perhaps both) may appear to the patient to be normal and no history bearing on the lesions may be obtained. Fracture of a cyst wall of any of these bones and the development of osteoarthritic changes in late adult life may lead to radiographic detection of the lesions.

In some cases these changes are associated with definite evidence of rheumatoid or osteoarthritic changes in the neighbouring joints. In an infant, age 3½ years suffering with Still's Disease the whole of the cancellous structure of the carpal bones had been destroyed, but in others, at ages varying from adolescence to old age, no such evidence may be present and the cause for the lesions cannot be explained. The appearances suggest occlusion of the nutrient vessel with absorption of the cancellous tissue—the remaining shell being kept alive by diffusion from the periphery. The lesions are often symptomless but trauma may result in fracture of the weakened bone and attract attention. *Köhler* records a case, a woman, in whom cyst-like changes were present in the trapezium and base of the first metacarpal. There was a history of lifting a heavy weight, after which the patient complained of pain, first in one wrist, then the other.

One fragment of the scaphoid—usually the proximal—may gradually show the signs of avascular necrosis: while the neighbouring bone as a result of immobilisation, shows a progressive decalcification, this fragment appears to attract calcium and become denser; its outlines are clearly preserved (see Fig. 68 A and B). These radiographs illustrated that the consequences to the bones or joints of a recent injury may not be

revealed by radiographs for some weeks—the latent negative radiographic period—and that signs of an old injury may cause one to overlook the necessity for a later examination

This density may persist for rather more than a year then its appearances suggest that the acquired calcium is being slowly transferred for the density appears to be melting away and eventually before acquiring normal density and structure the fragment appears less dense than the adjacent bones. Substitution of the necrotic bone in this site may take 2 to 3 years



Fig 68A. Old ununited fracture of scaphoid 20/8/37 Note the false joint between the two fragments. Note also the pointing of the radial styloid indicating that it had been damaged a long time ago No sign of recent injury



Fig 68B. Same as 68A, but on 30/10/37 Note that the acute trauma for which 68A was taken has resulted in avascular necrosis of the proximal fragment of the scaphoid and Sudeck atrophy of the other bones of the wrist and hand.

Bipartite Scaphoids are not rare and are usually bilateral—a factor which is of the utmost importance in assessing the damage to a wrist in which the scaphoid appears to be in two parts. If the radiographs are taken some time after the injury the fractured scaphoid and the bipartite congenital scaphoid may present similar appearances, because the fragments frequently fail to fuse Some authorities state that fractures of the scaphoid never heal by bone but this is not in accordance with my experience The ununited fracture is usually associated with evidence of traumatic arthritis in the involved surfaces (see Fig 68 A) When evidence of an old injury to bone is discovered on radiographs for a recent injury it is well to realise that the recent injury might have caused damage which is not yet indicated (see Figs. 68 A and B)

I have radiographed the wrists of patients who showed a fractured scaphoid which it is now impossible to distinguish from the opposite normal side—bone fusion of the two fragments being complete and the line of fracture indefinable

Radiographs showing bilateral bipartite scaphoids are published by *Ogilvie*[3] *Todd*[1] *Speed* and *Schnek* radiographs of fractured scaphoids are included in their articles. The radiographic appearances of bipartite and fractured scaphoids are illustrated by *Lachapèle* *Darleux* illustrates a fractured scaphoid in association with a dislocated semilunar

Unusual fractures and dislocations of the carpal bones are recorded, such as isolated fracture of the pisiform (*Kremser*[1]), trapezium (*W Jaeger*)

It is very essential that antero-posterior oblique and lateral radiographs are taken in case of injury in the region of the wrist joint. When a scaphoid fracture is suspected a further radiograph with ulnar deviation of the hand or with the dorsum of the base of the first metacarpal resting on the film may give additional evidence, as the shadow of the distal extremity of the bone may be superimposed on the middle third as in Fig 60 In those cases in which the clinical evidence suggests fracture of the scaphoid but the ordinary radiographs fail to show a fracture it is advisable to take a radiograph showing *the articular surface of* the lower end of the radius, for this may be fractured opposite the scaphoid-semilunar joint yet not show on the ordinary projections. To do this the hand is placed flat on the film with the elbow elevated so that the anterior surface of the forearm is at an angle of 45° with the film, the central X Ray being directed vertically on to the film.



Fig 60 Radiograph of the hand in ulnar deviation to show fracture of scaphoid which escaped notice on the ordinary projection.

Injuries to the wrist are frequently associated with the separation of small fragments from the posterior surface of one or other of the carpal bones which it may be difficult to determine—but the scaphoid and cuneiform and unciform appear to be the more commonly affected.

The typical appearances of displaced semilunar bones are shown by *Wakeley*[4]

Injuries of the first metacarpo-carpal joint are relatively common They are frequently associated with a fracture of the base of the first metacarpal, which may also be dislocated by the injury More rarely only the trapezium is fractured. The injury is usually produced by a blow directed by or against the thumb along the direction of the first metacarpal as in boxing The fact that the joints into which the trapezium enters are the commonest in the wrist to show chronic arthritic changes also points to the greater liability of the trapezium to trauma.

Semilunar Malacia. *Kienböck* described a condition in the semilunar which presents radiographic features resembling those seen in the epiphysis of the head of the femur in Osteochondritis Femoris Juvenilis. There is frequently a history of trauma for

which the wrist may have been radiographed and a negative report issued The wrist may continue to give pain for a varying period of from one to fourteen days, but gradually the pain ceases and an ensuing period of quiescence suggests that the injury has been completely repaired. Slight osteoporosis and compression of the bone may be suggested by radiographs. After a variable time the patient again begins to experience discomfort, limitation of movement and eventually pain with swelling of the wrist. A radiograph at this stage will usually show irregular calcification of the semilunar some areas being almost devoid of calcium, others being so relatively dense with calcium as to suggest sequestra The general outline of the bone may be preserved but in other cases the bone



FIG 70. Kienböck malacia. 20/6/44 19/9/44 16/1/45 and 23/1/47

shows a compression deformity of greater or lesser degree. In the former case the islands of bone of increased density appear to have been crushed together and the wedge-shaped structure has a density much greater than the other bones of the wrist (see Fig 70)

If the general outline of the bone has been preserved, the irregularly calcified areas blend and the condition passes, leaving little deformity to indicate that a lesion has been present If compression has taken place the fragments eventually blend together in the deformed shape, and the symptoms subside Owing to the deformity of the bone, the joints into which the deformed articular surfaces enter are subjected to abnormal stresses and strains, and early chronic arthritic changes develop, bringing with them the third period of discomfort and limitation of movement. On the advice of the author surgeons have immobilised affected wrists in plaster for a year but little radiographic change or clinical improvement has been noted, consequently the deformed bone has

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FIG. 70 Kienböck's malacia. 30/6/44, 19/9/44 16/1/45 and 23/1/47

shows a compression deformity of greater or lesser degree. In the former case the islands of bone of increased density appear to have been crushed together and the wedge-shaped structure has a density much greater than the other bones of the wrist (see Fig 70).

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been removed. As shown elsewhere, it takes upwards of 4 years to secure substitution of avascular bone of this nature and a longer period of immobilisation may secure a better subsequent result than surgical excision.

In a patient who gave a history of a fall on the hand 3 months previously little could be detected beyond slight deformity of the semilunar but after 12 months typical Kienböck signs were present.

One patient aged 32 had the typical appearances for 8 years. He was subject to repeated bouts of painful disablement after heavy work. Eight months' immobilisation did not have any apparent effect.

Many explanations have been given for these changes, including injury to blood vessels, tearing of ligaments and interference with the nutrition of the bone, embolism, quiet necrosis, necrosis due to low grade septic organisms and trauma. The radiographic appearances suggest as the most likely cause, a fracture of the cancellous bone which is rendered avascular and may be eventually compressed by pressure and muscle pull during the plastic reorganising stage of the bone injury. As suggested elsewhere some additional factor to fracture must exist.

O. Hulton[2] after examining the radiographs of 400 normal wrist joints, concluded that in 23 per cent. of cases the ulna was shorter than the radius so that the articular surfaces were not on the same plane. He found *Kienböck's* traumatic malacia only in those patients who showed a shorter ulna. This feature is not shown in Fig. 70.

This rather suggests that the semilunar bone is more prone to severe injury if the ulna is short. After examining a large number of radiographs of the wrists of children one gets the impression that the shortening of the ulna may be due to infantile rickets or scurvy (see Fig. 75 B). But in the author's series there are radiographs of semilunar malacia which show the radius and ulna to be of normal length, even after very marked collapse of the affected bone.

That rupture of ligaments and interference with the nutrition of the bone does not alone account for the condition is seen by the study of a series of radiographs taken at intervals following complete forward dislocation of the semilunar. Radiographs taken following reduction show rarefaction of all the carpal bones except the replaced semilunar which retains its density for several weeks. The appearance of fragmentation and crushing, seen at one stage of *Kienböck's* Malacia, does not occur but often after an interval of several months, evidence of new bone formation may be seen, and, later the onset of chronic arthritis early in life. Dislocation of the semilunar bone, even though completely reduced, is so frequently followed by disabling traumatic arthritis that some surgeons prefer to excise the bone rather than reduce the dislocation.

As indicated elsewhere these secondary changes may be limited by more careful and prolonged immobilisation. The excellent radiographic appearances immediately following reduction are possibly responsible for failure to give the damaged tissues a chance to recover completely. The patient is frequently advised to use the joint as much as possible to keep it from getting stiff and dismissed from further treatment. It is not until considerable disablement and further radiography after many months that the damage present is appreciated. It may be that a bone graft fusing the scaphoid to the condensed bone may result in revascularisation. Congenital fusion of these bones is associated with good function.

A good example of isolated dislocation of the scaphoid is published by *A. Overkof*. *Preiser*, *Martin* and *Roesler*, *Santocki* and *Kopelmann* have described a malacia in the carpal scaphoid. Similar changes have been seen by the author in both pisiforms.

Osteoporosis Associated with Trauma. Osteoporosis of the bones of the wrist and hand following injuries in the neighbourhood is sometimes so marked that only a faint

thin shadow of the outline of the cancellous structures remains The compact tissue of the shafts of the metacarpals and phalanges is in distinct contrast In some cases the osteoporosis has a very irregular distribution—small rounded areas of decalcification may be indicated in the radiographs of the bones—these areas may be so discrete as to suggest foci of infection or malignant disease and have been interpreted as such. This is now referred to as **Sudeck s atrophy** of the bone

In those cases with avascular necrosis of a fragment of bone the latter appears to absorb calcium and become denser at the expense of the adjacent normal bone (see Fig 68 B) The author[10] has illustrated the osteoporosis which follows trauma.

Leriche and *Fontain* show a series of radiographs of sixteen cases of painful post traumatic osteoporosis before and after periarterial sympathectomy They state that the pain disappears within a few hours, and within a few weeks the radiographs show a return of the calcium. *Turner* in describing extreme decalcification of the bones of the hand following a cat bite, attributes the condition to an injury to the dorsal interosseous nerve as it crosses the lower end of the radius. He treated one case which failed to respond to physical remedies by injecting ½ gram of 5 per cent. tincture of iodine deeply under the skin in the area of the irritable point of the nerve. This caused a violent burning pain for a short time, but the other pain subsided and the patient made a complete recovery



Fig 71. Radiograph of the wrist of a man aged 49 showing early tuberculosis of the os magnum Not (1) the outline of the periphery of the bone is woolly and ill-defined while the periphery of the other carpal bones is sharp; (2) marked osteoporosis of all cancellous bone but relative density of compact bone of metacarpals; (3) band of osteoporosis at the lower end of the diaphysis marking out the fused epiphyseal line

Tuberculosis Tuberculosis of the wrist may commence in any of the carpal bones or in the synovial membrane. If the primary focus occurs in one of the bones, an area of rarefaction is seen, which in the early stages may show a certain amount of density of the periphery Usually however the radiograph shows marked osteoporosis of all the carpal bones and it may be impossible, owing to this general osteoporosis to pick out the primary focus. Attention should be directed to the periphery of the bones.

In the earlier stages the periphery of the diseased bone is ill-defined whereas the non-affected bone shows a thin sharp periphery—contrast the outline of the os magnum and the other carpal bones in Fig 71 Marked osteoporosis of the carpal bones in tuberculosis is associated with marked osteoporosis of the extremities of the metacarpals and phalanges. The whole of the cancellous bone of the wrist and hand appears to undergo great decalcification where as the compact bone of the shafts of the metacarpals and

phalanges retains for a time a considerable portion of calcium. The lower ends of the radius and ulna also show an osteoporosis, which, as in Fig 71 appears to be most marked at the end of the diaphysis, even though fusion of the epiphyses has occurred.

Radiographs at a later stage of the disease show destructive changes in the involved bone with consequent deformity Healing of the lesion is indicated by increased density of the bone trabeculæ, which have a coarser and more open structure than in normal bone, and by fusion of the involved bones—the unaffected bones having sharp, well defined borders. *Hanke* describes and illustrates tuberculosis commencing in the os magnum (one case) and semilunar (two cases)

The author reported caries in a man of 62 years of age. Radiographs showed scalloping of lower ends of radius and ulna with some degree of sclerosis of the walls of the scalloped bays and cyst like changes in scaphoid Very slight pain or disability were present The appearances resembled severe osteoarthritis Histological examination showed typical tuberculous granulation tissue.



Examples have also been demonstrated by *Worster Drought.*

The extensive destruction associated with **Arthritis Psoriatica** may suggest a neurotrophic lesion (see Fig 48 K)

Two unusual bilateral examples of lesions in the carpo-metacarpal and the inferior radio-ulnar joints which appear to be associated with some nerve lesion and repeated injuries are shown in Figs. 72 and 73

Osteoarthritis of the carpal joints occurs with deformity of the individual bones, narrowing of the joint spaces sclerosis of the approximated joint surfaces and new bone



FIG 73. Unusual trophic lesions at inferior radio-ulnar joint and 1st carpo-metacarpal joint.

formation around the periphery of the bones resulting in an increased density of the joint The joints into which the trapezium enters appear to be most commonly affected with osteoarthritis

Rheumatoid Arthritis. Rheumatoid arthritis in its early stages produces the radiographic appearance of osteoporosis with blurring of the outline of the periphery of the bones Later the appearances suggest that a plastic fluid has cemented together all the elements of the carpus and finally the carpus is completely fused with obliteration of the outlines of the individual bones in the central carpal joints For the most part the osteoporosis persists

In **Still's Disease** the carpal bones may lose their internal structure

Gonococcal Arthritis The radiographic appearance is similar to that of rheumatoid arthritis but is usually monarticular and with the passage of the acute phase the osteo-

phalanges retains for a time a considerable portion of calcium. The lower ends of the radius and ulna also show an osteoporosis, which, as in Fig 71 appears to be most marked at the end of the diaphysis, even though fusion of the epiphyses has occurred.

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FIG. 72. Unusual trophic lesion at inferior radio-ulnar joint (bilateral).

Charcot's Joints. Neurotrophic wrist joints are seen in Syringomyelia, Syphilis, and Leprosy In some the underlying cause cannot be found. They have been seen in patients giving a history of rheumatic fever in childhood as the only illness. They may occur bilaterally Their immediate onset is usually the result of trauma. The radiographic appearance of the early lesion is one which suggests an increase in the joint spaces with a certain lack of sharpness in the peripheral outline and a suggestion of a small quantity of flocculent precipitate of calcium. Later destructive erosion takes place in the extremities of the bones of the joint, the normal outline is obliterated and a larger amount of flocculent calcium is shown in the neighbourhood of the enlarged joint.

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Gonococcal Arthritis. The radiographic appearance is similar to that of rheumatoid arthritis but is usually monarticular and with the passage of the acute phase the osteo-

porosis gradually disappears Fusion of the joint surfaces may not occur The condition is illustrated in Fig 74

Tumours. Examples of most of the bone tumours have been recorded associated with the bones of the area Their distinctive features are similar to those seen in other bones and are described in the chapter on bone tumours



FIG 74 Radiograph showing marked osteoporosis of the carpus and neighbouring bones in a case of gonococcal arthritis.

In the course of an investigation of the bones of the hands and feet *Kahn* found 143 lesions (including **Exostosis 40 Chondromyxoma 45 Giant-cell Tumour 12, Osteitis Fibrosa 6 Xanthoma of Tendons 20 Sarcoma 5 Carcinoma 6**)

Secondary carcinoma and epithelioma from primaries in the lung and elsewhere may develop in the bones of the hand and wrist Such lesions may be mistaken for tuberculous foci as they are associated with a long negative radiographic latent period and progressive decalcification of all the bones of the affected hand The lesions are usually essentially osteolytic and show no osteoplastic reaction Pain is a very prominent clinical feature (see Fig 497)

CHAPTER IV

LOWER ENDS OF RADIUS AND ULNA

The lower extremity of the diaphysis of the radius soon after birth has a straight or slightly convex border towards the wrist joint, particularly on its inner half. The lower end of the ulna is usually straight, but it also may have a slight concavity or convexity. The osseous nucleus for the distal epiphysis of the radius may be present at birth, and it can generally be shown on radiographs by the end of the first year of life but the epiphysis for the lower end of the ulna does not appear until after the fourth year of life. The epiphyses unite about the eighteenth year of life.

Delay in the appearance of these nuclei occurs not only in well known conditions associated with endocrine disturbance (pituitary and thyroid dysfunction) but in children who do not present any characteristic signs or symptoms (see p. 20).

By the age of 5 in most children radiographs show that the radial epiphysis is about as broad as the lower end of the diaphysis. It is thicker on its lateral than on its medial aspect and presents a slight distal concavity. The lower ends of the diaphyses of the ulna and radius at this age are slightly convex towards the wrist. The metaphyseal borders of the radius are regular and clearly defined.

EVIDENCE OF GENERALISED BONE DISEASE AS SEEN IN THE BONES OF THE HAND

Rickets. In radiographs of active florid rickets of infancy the bones show a general osteoporosis or rarefaction. Whereas in the shafts of normal phalanges, metacarpals, and lower ends of the shafts of the radius and ulna, a definite differentiation of compact tissue is indicated by relative peripheral sclerosis, in active rickets this cortical density is lacking; indeed, there may be definite cortical rarefaction, and consequently the detail of the trabeculae of the cancellous bone is more apparent than in the normal bone. The extremities of the ulna and radius in addition are broader than normal, and in the active infant show definite marked concavity or cupping. The borders of these cupped extremities appear ill-defined or feathery. The epiphysis of the radius at this stage may have little density and its borders may be indefinite. Soon after the application of remedial measures such as sunlight and feeding with cod liver oil, an increase in the density of the borders of the cupped extremities of the radius and ulna takes place. This density of the growing extremity is greater than that of the other bone structure. (See General Discussion, pp. 583–8.)

The outline, though irregular, is no longer indefinite or feathery but can be fairly clearly defined. Increased density of the well of the cup may give the appearance of a second line. The borders of the epiphysis of the radius also become clearly defined.

After an interval of 4 to 6 weeks, depending on the patient and the treatment given, the cupped extremity flattens out and diminishes in width. Extending from the metaphyseal surface up the shaft of the bones for a little more than ½ inch will be shown a zone of osteoid tissue of less density than the remainder of the shaft. The trabeculation of this area is of the ground-glass type—much finer than seen higher in the shaft. Deep narrow clefts into this zone may be present at this stage due to the disordered and irregular growth during the active period of rickets. These clefts are gradually obliterated and after about three months' treatment the bones are assuming their normal shape; peripheral density begins to appear; the zone of rarefied bone becomes obliterated

The extremities, however may retain a slight concavity for some time, and owing to the growth disturbance the distal surface of the ulna and radius may not be on the

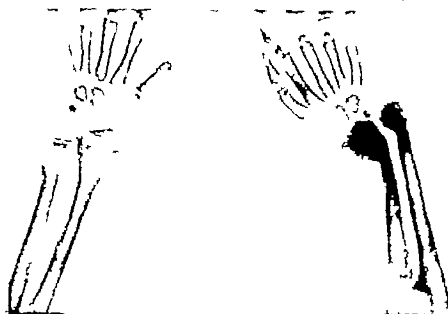


FIG 73A. Radiograph of the wrists of M. G aged 5 years (28 5 28). Active rickets. Note the bulbous appearance and inward bending of the distal extremities of the radius and ulna.

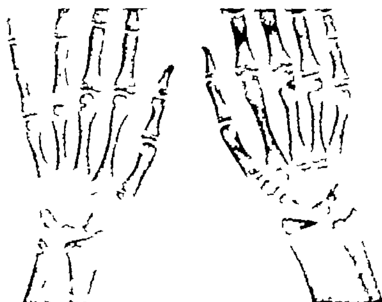


FIG 73B. Radiograph of the wrists of M. G. (same patient as Fig 73A), age 10 years, showing only slight shortening of the ulna on both sides. Complete disappearance of the rachitic changes.

same plane—frequently the ulna is the shorter The dense line shown when repair of the bone commenced is frequently obliterated before the concavities are filled in or the

rarefied zone of new bone has disappeared (see Fig 80 A–C) The transverse lines shown on radiographs parallel to the epiphyseal line are not due to rickets.

During the active stage multiple fractures of the long bones may be seen These readily heal with callus, and after the rachitic process has disappeared no trace of the fracture may be detected if proper splinting be applied at the time to prevent deformity

Untreated rickets results in marked deformity of the long bones due to bending of the soft bone. This is well illustrated in Fig 75 A (taken 28/5/28) This radiograph shows that the distal extremities of the right ulna and radius are bulbous, and their peripheries hazy and they have a marked inward bending The left wrist shows active rachitic changes. The different appearance of the two sides was probably due to trauma of the right side during the active phase as the lesions in florid rickets are usually symmetrical Owing to the atypical appearance of the right wrist the Wassermann reaction was taken and found to be negative No evidence of renal disorder could be detected by biochemical examinations of the urine and blood The child was put on ultra-violet radiation, and splinting and manipulation of the deformed right wrist was carried out by *Naughton Dunn* The remarkable result of this treatment is shown in Fig 75, B (radiograph taken 23/2/33) Except for a slight shortening of the ulna on both sides, the bones at the wrists appear to be normal no deformity can be seen on clinical examination. (See also Fœtal Rickets, p 585)



FIG. 76. Radiograph of the wrist of a youth aged 17 showing Type A—the non-bending form of renal rickets. Note the thick metaphyses; the fluffy irregular cupped extremity of the diaphyses a distinct from the regularity of the metaphyseal surface of the epiphyses. Expansion of the lower end of the diaphysis is not so marked as in infantile rickets. Little change in the phalanges and metacarpals.

Renal Rickets. The association of rachitic changes in the bones with chronic interstitial nephritis was first noted by *Fletcher*

The radiographic appearance of rickets occurring in association with nephritis appears to fall into two very distinct types

Type A. In the one group the shafts of the bones are of normal shape and slightly

increased density—they do not show any bending They show none of the characters of infantile rickets. The characteristic appearance is shown at the distal *extremities of* the diaphyses of the radius and ulna (see Fig 76)



Fig. 77 Radiograph of patient age 21 showing that fusion of the epiphysis and diaphyses of the metacarpals and phalanges has occurred. The cancellous appearance of all the bones of the hand is now very distinctive and unlike any other conditions. The radial and ulnar epiphyses have not yet fused. *Type B renal rickets.*

The metaphysis is thick, the distal extremities of the diaphyses of the radius and ulna are cupped and their metaphyseal margins are irregular and fluffy In contrast with Infantile Rickets the epiphyseal periphery on the other hand, is well defined even on it metaphyseal surface In the severe cases the metacarpal and phalangeal metaphyses

h… w… milar appearances and … as in infantile … diaphyses … how rather an increased density and … an l medulla … no definite compact ti… sue can …



In this type owing to disorganisation, the metaphysis can… stresses and strains as the normal and the epiphysis may be d… illustrations) The changes may be more extensive on one side t… be due to excessive strain of the affected metaphysis which le… distribution of the ossifying cartilage. Under these circumsta…

diaphysis may present a disorganised fragmented condition with displacement of the epiphysis, which appearance *Teall* aptly likened to that of a broken end of a rotten wooden stump. With improvement of the renal condition the radiograph will show an improvement in the condition of the metaphysis.

In one case, Fig. 76, the radiographic appearance of rickets disappeared within a month and recurred again after several months.

I have not found any changes in the bones of the skull in this type of renal rickets.

Type B. The second type is associated with a much more severe renal damage and the tendency is for the bone lesions to progress. They show general osteoporosis and an obliteration of all compact tissue. The cortical bone of the phalanges and metacarpals appears rather more rarefied than the cancellous bone, but it possesses a very regular and definite peripheral margin (compare Fig. 77 with Fig. 70). The cancellous structure of an almost uniform, but more open or coarse reticulation than the normal, extends throughout the whole of the long bones of the hand, and there is no evidence of a medullary cavity as seen in the normal. The metaphysis is much thicker; the lower ends of the diaphyses deeply cupped—the cupped extremity having a ground-glass, structureless appearance as if the cancellous bone has undergone a mucinous degeneration (see Fig. 77). This is mostly osteoid tissue.

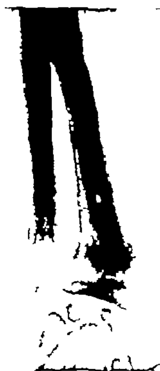


Fig. 79. Hyperparathyroidism. No compact tissue; thick metaphyses with woolly borders.

In this type the bones are softer and more plastic than normal, and if the patient's condition permits him to subject them to weight bearing or strain they will bend as in osteomalacia. The terminal phalanges may be almost completely decalcified and small cyst-like areas of cancellous destruction may appear in the phalanges or metacarpals. All the arteries of the hands (and of the whole body) may be calcified at a relatively early age. The bones of the skull will show very marked changes (see Fig. 433). The parathyroids are found to be hypertrophied in this type.

Changes in the bones indistinguishable from ordinary rickets, often referred to as Late Rickets, which do not respond to the exhibition of vitamins or ultra violet light persist for many years. In some cases of this nature a periodic reactivation followed by healing appears in the rachitic process. In some such cases osteoid tissue ceases to be laid down at the growth cartilage and the bone here becomes clearly defined—a zone of osteoid immediately proximal to this shows no cancellous trabeculation. Multiple transverse trabeculæ which have been referred to as *lines of cessation of growth*, may be eventually seen in these cases.

Hyperparathyroidism. The appearances of the bones of the hands and forearm in hyperparathyroidism are characteristic. They are well illustrated in Fig. 78. The absence of compact tissue and the cancellous appearance of the bones due to this and the changed cancellous pattern, with here and there small ill-defined areas of decalcification or perhaps having the definition which permits of the term "cysts" (hence the term "osteitis fibrosa cystica"), the crenated borders of some of the phalanges, the expansion and decalcification of the tufts of the terminal phalanges form a unique

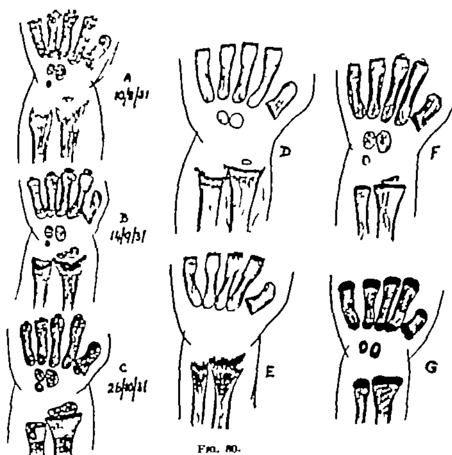


FIG. 80.

A. Florid rickets in wrist of a child aged 2 years. Note the general osteoporosis with the suggestion of a layer of more rarefied periosteal bone along the shafts. Cupping of the ends of the diaphyses, the extremities of which are ill-defined and irregular. Ill-defined epiphyses.

B. Same wrist as A one month later—ultra-violet light exposures during the interval. Note that the extremities of the diaphyses are now clearly defined, that the metacarpals have almost a normal appearance, but the cupped extremities of the ulna and radius show a dense irregular margin. The zone of bone immediately proximal to this is relatively rarefied compared to the shaft and exhibits very fine reticulations.

C. Same wrist as A, ten weeks later showing that the bones have now almost normal density. There is still some sclerosis of the margin of the end of the diaphysis of the ulna and radius, and there is a deep cleft shown in the extremity of the ulna. The zone of new bone at the end of the diaphysis is a little more than ¼ inch in thickness and has a ground-glass appearance. Four weeks after this the bones had a normal radiographic appearance.

D. Scurvy in wrist of a child of 10 months. Note the narrow dense band of bone at the distal extremity of the radius and ulna, which appears to project beyond the limits of the width of the shaft. Immediately proximal to this is a narrow zone of decalcified bone. A thin line of periosteal new bone is shown along the diaphyses of the radius and ulna. The bones are generally rarefied and show a fine cortex.

E. Syphilis in wrist of a child of 2 months showing irregular band of dense bone at the distal extremities of the radius and ulna with an area of subperiosteal erosion on the outer side of the radius. There is a zone of decalcified bone proximal to the dense extremity which is succeeded by a denser zone of bone.

F. Wrist of child of 2 years shows dense zone at extremity of diaphyses due to lead ingestion.

G. Albers-Schönberg's disease in bones of a child of 11 months. Dense calcification has begun at the extremities of the diaphyses and in the periphery of the carpal bones.

composite picture. The only condition which has radiographic features resembling it is renal rickets, type B but in this the resembling features are probably due to a secondary hyperparathyroidism

Fig 79 is of a young person with hyperparathyroidism and it shows appearances resembling Type B rickets—they disappeared following the removal of a parathyroid tumour

For further details and differential diagnosis see pp. 597–600.

Idiopathic Steatorrhoea is associated with characteristic appearances (see Fig 51).

Osteitis Deformans (Paget's Disease) Osteitis deformans of the hand may present the three different radiographic appearances in individual bones as described on pp. 326 and 327 Other parts of the skeleton should be radiographed to confirm the diagnosis.

Scurvy (Barlow's Disease) (Fig 80 D). In scurvy the radiographs show rather different appearances. The cortical compact layer of the long bones appears to be thinned from the medullary side rather than rarefied, so that the bones have a sharp clearly-defined outline with an increased translucency of the shafts, suggesting rarefaction or complete destruction of the cancellous trabeculae. This is well seen in the epiphyses, particularly in the larger ones at the knee joint, which appear to consist only of a thin shell of bone. In the wrist the distal epiphyses may not show this appearance like the distal extremities of the radius and ulna in rickets, they may appear of a woolly consistency The growing extremities of the radius and ulna show a thin terminal margin of dense bone which often appears to project beyond the width of the diaphysis and may present the appearance of having slipped slightly off the end of the diaphysis. This dense margin lies upon a narrow zone of decalcified bone which appears to permit lateral displacement or compression. The peripheral margin of the epiphyses is very thin, but sharply defined, the cancellous trabeculation of the bone often not showing Along the shafts of the long bones a thin line of periosteal new bone may be seen. If subperiosteal hæmorrhage has occurred a hazy band of shadow with a well-defined periphery may be seen along the periphery of the shaft, often widest just above the end of the diaphysis and gradually diminishing until it blends with the shaft about its middle third It may extend the whole length of the diaphysis After a week or so the definition of the subperiosteal hæmorrhage becomes more marked; it may become denser than the shaft of the diaphysis owing to calcium deposit. When healing commences, the dense line at the extremity of the diaphysis is absorbed and new bone is laid down in the epiphysis around the thin shell already described, which preserves its shape and size for a number of years, its contents still appearing to be devoid of or showing only coarse trabeculation. The calcified subperiosteal hæmatoma is gradually absorbed, and after a few years only the larger epiphyses and one or more transverse lines across the extremities of the diaphyses may give an indication of past scurvy

Large hæmatomata may envelop a diaphysis within first 8 months of life (see Fig 494)

Syphilis (Fig 80 E) Similar radiographic appearances to those seen in scurvy are seen in the radiographs of the bones of congenital syphilitic babies during the first three months of life. This is an earlier period, however than that associated with the appearance of scurvy i.e. six months to two years. The presence of subperiosteal erosions near the growing ends of the diaphyses and the dentate appearance of the dense metaphyseal margin, or the indications of ossifying subperiosteal hæmorrhages, in a baby of less than three months is practically diagnostic of congenital syphilis. As in scurvy the dense line of the extremity rests on a zone of decalcified bone and may be displaced but in syphilis the latter rests on a zone of denser cancellous bone (see Fig 80, D and Fig 105)

Radiographs of a baby 1 month old showed expansion and bending of the inferior

extremities of the radius and ulna—the latter being then as broad as the radius. The cancellous structure of these extremities was irregular The olecranon was irregular and osteoporotic No other bones of the upper or lower extremities showed changes Other cases have been seen in which infants at 1 week have shown disorganisation of all the diaphyseal extremities.

Syphilitic Hyperplastic Ossifying Periostitis resembles the appearance of the ossifying subperiosteal hæmorrhage of scurvy but in syphilis the epiphyses tend to show a condensed nucleus, whereas in scurvy the epiphyses usually are devoid of internal structure

In case of doubt it is advisable to radiograph other bones of the skeleton—the knees for choice—and these radiographs may give the necessary data for diagnosis *see p 178 and Figs. 103 109*

J Caffey illustrated multiple transverse lines across the diaphyseal extremities in the bones of infants whose mothers, affected with syphilis, were treated with bismuth during pregnancy He considers that the lines were due to the bismuth medication

Lead (Fig 80 F) It has been observed that children who ingest lead tend to deposit it in the growing bones, and radiographs of the growing ends of long bones—such as the radius and ulna—show a line of dense bone. *Vogt*[1] found that these zones of dense bone at the extremities of the diaphyses contain less calcium, but four times as much lead. He shows a series of good radiographs illustrating the condition. Similar appearances are shown by *Caffey* The zone of condensation differs from that of scurvy in that it is not distal to a zone of decalcified bone.

Phosphorus. Remarkable lines of condensation are shown in the radiographs by *Gottesleben* and *Kemkes* at the growing ends of the bones of children who have had phosphorus medication From the distribution of these lines *Gottesleben* deduces that growth is irregular greatest in Summer least in Winter greater in the Spring than in the Autumn

Albers-Schönberg's Disease (Marble or Chalky Bones) (Figs 81 and 82) In this condition the infant may only show a condensation at the ends of the diaphyses of the long bones, as in Fig 81 and in the case of a child of 11½ months described by *Karshner*[1] Fig 82 shows the characteristic appearances in the adolescent. The radiographs may show a very irregular deposition of chalk as in the cases described by *Alexander* and *Wakeley*[2]



FIG 81 Radiograph of the hand of a girl aged 10 months, showing zones of dense bone at the growing extremities of the diaphyses and around the osseous nuclei of the two carpal bones. Early case of Albers-Schönberg's disease

Goetsky and *Wells* described in 1914 a case of myxœdema with transverse striations

Polyostotic Fibrous Dysplasia, Polycystic Dysplasia (see Fig 84, A and B) **Chondro-osteo-dystrophy Achondroplasia Multiple Exostoses Multiple Enchondromata** (see Fig 100) are often the cause of irregularity of outline of the lower end of the radius and ulna and their characteristic features are described in previous paragraphs

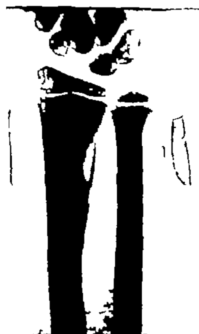


FIG 84A. Polycystic dysplasia. One of a number of isolated lesions



FIG 84B. Polycystic dysplasia. Same limb 4 years after See also Fig 314.

Congenital Deformities. Congenital deformities of the lower ends of the ulna and radius are met with They vary *in extent from complete* absence of one of the bones to small irregularities of the distal extremities. Congenital absence of the whole radius is perhaps the most distinctive and serious condition. It is usually associated with congenital absence of the thumb and its metacarpal (so-called congenital club hand) and a constitution which renders the child liable to succumb to the intercurrent diseases *of childhood.*

Kato has reviewed the literature of 253 reported cases in which unilateral and bilateral examples with partial or complete absence occur

Fractures of the Lower End of the Radius and Ulna The radiographic appearances of fractures of the lower end of the radius and ulna are shown in most text books of surgery

Evidence of damage to the growth cartilage may not be seen until at least 2 weeks have elapsed. It then appears as a zone of increased density with an ill-defined proximal border at the lower end of the radial diaphysis.

Thurston Holland has illustrated that in separation of the epiphysis a flake of bone from the extremity of the diaphysis is carried with the epiphysis Backward displacement of the radial epiphysis is by far the most common. The ulnar styloid frequently remains ununited following injury

In some cases the radiographs suggest that it has never been fused with the other portion of the epiphysis.

Fractures of the cancellous bone occur without any apparent alteration in th alignment of the periphery of the bones, as shown by the radiograph and unless caref

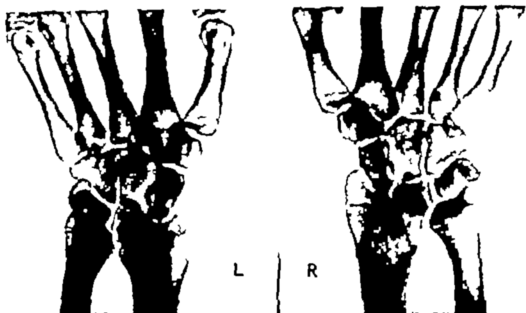


FIG. 83A. Antero-posterior radiograph of Madelung's deformity Bilateral.

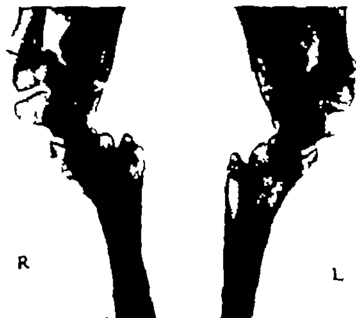


FIG. 83B. Lateral radiograph of Madelung's deformity Bilateral
Note bayonet-like projection of hands.

scrutiny be made for cleavage of the cancellous trabeculæ the lesion may be miss Evidence of its existence may be definitely shown on radiographs at a later date

Radiographs to show fractures of the lower ends of the radius and ulna in osteogenesis imperfecta may reveal marked tortuous calcified arteries, as shown in the illustrations of *Johannson.*[1] Similar changes have been seen by the author in Type B renal rickets.

Madelung's Deformity The deformity described by *Madelung* in 1879 is associated with a defective development of the inner third of the growth cartilage at the lower end of the radius which results in stunted growth of the epiphysis and diaphysis on the inner side Growth of the outer two-thirds of the shaft and of the epiphysis continues, and, as a result, the radial shaft is bowed backwards and the interosseous space is increased the lower end of the ulna is subluxated backwards, while the radial epiphysis appears to peter out towards the inner third where early fusion with the diaphysis is suggested. The articular radial surface, instead of presenting the normal regular concavity for the carpus, is markedly oblique the inner surface, which is largely diaphyseal, is cupped and its superior margin is pressed out towards the ulna so as to resemble a small exostosis. The bone surrounding this cup has a diminished function which is reflected in its lessened density while the more prominent lower extremity of the ulna shows a definite increase in density The carpus, occupying the triangular gap between the oblique surface of the radius and the lower end of the ulna, forms a *pyramidal group of bones with the semilunar at the apex of the group* (see Figs. 85 A and B).

The result of these irregularities is the carrying forward of the hand and carpus at the radio-carpal joint to produce, on lateral viewing a bayonet-like projection of the hand on the shortened forearm. Viewed from the back the hand shows some degree of ulnar deviation. A few cases have been described in which the curvature of the radius has been reversed, leading to an anterior displacement of the lower end of the ulna and a backward projection of the hand. The deformity is usually bilateral, but in some cases the deformity is more marked on one side than the other One side, more often the left side, may be normal. It is much more frequent in the female and is usually first noticed during adolescence.

Some cases of familial distribution have been noticed, and I have seen it in twins. As a result of the defective growth of the lower end of the radius and the resultant deformities, the hand and wrist are weak, and while flexion may be increased, the other movements are restricted and sometimes painful. *The cause of the condition is unknown,* it is not related to trauma or to infantile diseases such as rickets. It appears to be a localised chondro-osteo-dystrophy resembling that of cervical coxa vara.

J T Anton G B Reitz and *M B Spiegel* have analysed the findings in 171 reported cases.

Cases of Multiple Exotosis which are associated with stunted development and curvature of the radius and ulna have been wrongly described as Madelung's disease. The two conditions are distinct entities and should not be classified together To draw attention to the resemblance such a case might be described as a *Pseudo-Madelung Deformity*

Other authorities express different opinion as to aetiology Trauma, inflammation, neuro-muscular disorder dystrophy endocrine disturbances and rickets Thus *Jones* and *Lovett* describe the condition as an occupational deformity following rotating strain of the wrist and that it often occurs in charwomen.

Giant-celled Tumour The commonest tumour of the lower end of the radius is the giant-celled simple tumour (Tumeur à Myéloplaxes (*Nélaton*), Osteoclastoma, Myeloma, Myeloid Sarcoma). This growth frequently causes little pain in its early stages and usually there is a marked tumour before the patient is sent for radiographic examination

The radiographic appearances are typical (see Fig 80) If the tumour is radiographed early in its history only a suggestion of localised destruction of the cancellous bone may be seen without expansion of the shaft It is an endosteal tumour The involved bone is expanded throughout the extent of the tumour its compact cortex is thinned—or it may even be absorbed—its normal trabeculation is destroyed, and in its place a foam like bone structure is shown Fig 80 shows the tumour in an unusual site the lower end of the ulna


Fig 80. Osteoclastoma of ulna

The coarseness of the foam like bone varies In some cases it is fine in others the appearance of large bubbles is seen, while in others the central walls of this structure may be broken down completely or in part—only the periphery presenting an undulating appearance.

Cases do occur in which the process of expansion of the bone is concomitant with destruction of its trabeculation, and these cases may show only a regular thin bony casing to the tumour or no bony outline.

The rate of growth of the tumour to some extent accounts for its radiographic appearance as a general rule the slower the growth, the denser the involved bone. There is usually a very well-defined margin between the invaded and the non-invaded shaft, but there is no evidence of periosteal reaction in the shape of new bone formation either around the tumour or the normal shaft: the radiographs suggest that the bone is absorbed almost as quickly as it is laid down by the periosteum. The tumour may completely destroy the bony casing and invade the soft tissues, indicated on the radiographs by a break in continuity of the outline of the periphery of the bone On account of its size the tumour may cause a pressure absorption of the adjoining ulna. These simple tumours when cut into, usually show a reddish-brown discoloration but cases do occur in which the tumour tissue, though presenting similar histological features is white or yellowish throughout while others show fibrous, myxomatous or cartilaginous tissues with areas of calcification.

The response of these tumours to X radiation is illustrated and described on p. 701 Fig 487

Stewart illustrates a tumour at the lower end of the radius in a girl 6 years of age. His radiograph shows marked expansion of the lower half of the radius—the epiphysis appears to be spared. The outer wall of the tumour consists of a very thin regular bony casing the inner bony wall has been destroyed and there is a pressure atrophy of the shaft of the ulna for the distance of the involved bone. No evidence of bone trabeculation can be seen within the tumour At operation it was found that the inner wall had been destroyed and the tumour which was white and solid throughout, had invaded the soft tissues of the part.

In the history of the case it was stated that the swelling had been noticed 3 years before. In a recent letter *Professor Stewart* informs me that the patient died about 2 years later from a lung lesion. ? Metastases Neither the radiographic nor macroscopic appearances nor the age nor the clinical history are typical of osteoclastoma.

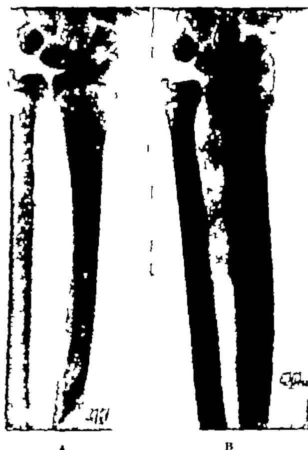
Kolodny [1] records that of the material submitted to the Registry of Bone Sarcoma,

the relative frequency of giant-celled tumours as compared with malignant bone tumours is as 1 2.

The tumour occurred in the bones of the upper extremity in 23 per cent. of cases, and in 40 per cent. of these the lower end of the radius was affected He uses a radiograph showing the typical appearance of the tumour in the lower end of the ulna—a position in which it is relatively rare See author's case, *Fig* 86

The author has shown that tuberculous osteomyelitis of the lower third of the radius may produce radiographic appearances which may be mistaken for those of this tumour He has not seen an osteoclastoma at this site at an age when the epiphysis had not united.

Osteochondritis Juvenilis. *Burns* has illustrated a case which he describes as Osteochondritis Juvenilis of the lower ulnar epiphysis in a boy of 10 years of age. His radiographs show a double epiphysis to the second metacarpal which is frequently associated with skeletal dysplasia.



A B

Fig 87A. Acute osteomyelitis (29/9 44 four days after onset). Note decalcification of lower end of radial diaphysis.

Fig 87B. Acute osteomyelitis (23/10/44). Note involucrum and erosion of original shaft.

Fractures which involve the epiphyseal line may result in marked shortening of the fractured bone owing to disturbance in the bone growth.

Dislocations. Dislocations of the radio-carpal and inferior radio-ulnar joint occur

These can be readily detected if radiographs in several planes are taken of both sides and compared (see Madelung's deformity Figs 85 A and B and multiple chondromata, Fig 90).

Gibson has recorded a series of cases

Acute Osteomyelitis. No indication of this condition may be detected within 10 days



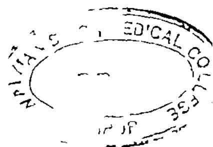


FIG. 86. Radiograph of the forearm showing chronic osteomyelitis of the shaft of the radius. Note the irregularity of the contour of the involucrum and the intact distal epiphysis. The elongated area of rarefaction in the middle third with the raised flap of involucrum at its proximal and outer extremity indicates an area from which a sequestrum has been removed. There is a thin line of periosteal new bone along the shaft of the ulna indicating periostitis.

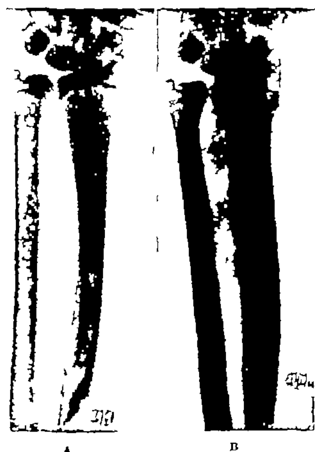
of the onset of prominent clinical signs. In some cases fracture initiates the onset of osteomyelitis Thus radiographs of the long bones of children have shown green stick fractures when radiographed immediately after an injury but further radiographs of the site two or more weeks later have shown the typical signs of osteomyelitis (see Figs 88 A and B p 104) The earliest indications defy lithographic illustrations It consists of a localised area of decalcification, usually near the extremity of the diaphysis

the relative frequency of giant-celled tumours as compared with malignant bone tumours is as 1 2

The tumour occurred in the bones of the upper extremity in 23 per cent. of cases, and in 40 per cent. of these the lower end of the radius was affected He uses a radiograph showing the typical appearance of the tumour in the lower end of the ulna—a position in which it is relatively rare. See author's case, Fig 80

The author has shown that tuberculous osteomyelitis of the lower third of the radius may produce radiographic appearances which may be mistaken for those of this tumour He has not seen an osteoclastoma at this site at an age when the epiphysis had not united.

Osteochondritis Juvenilis. *Burns* has illustrated a case which he describes as Osteochondritis Juvenilis of the lower ulnar epiphysis in a boy of 10 years of age. His radiographs show a double epiphysis to the second metacarpal which is frequently associated with skeletal dysplasia.



A B

Fig. 87A. Acute osteomyelitis (20/9/44 four days after onset). Note decalcification of lower end of radial diaphysis.

Fig 87B. Acute osteomyelitis (23/10 44). Note involucrum and erosion of original shaft.

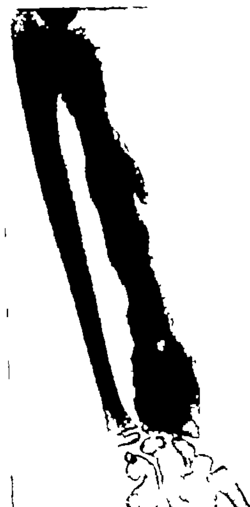
Fractures which involve the epiphyseal line may result in marked shortening of the fractured bone owing to disturbance in the bone growth.

Dislocations. Dislocations of the radio-carpal and inferior radio-ulnar joint occur

These can be readily detected if radiographs in several planes are taken of both sides and compared (see Madelung's deformity Figs 85 A and B and multiple chondromata Fig 90).

Gibson has recorded a series of cases

Acute Osteomyelitis. No indication of this condition may be detected within 10 days



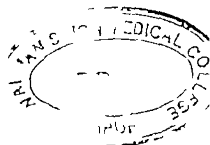


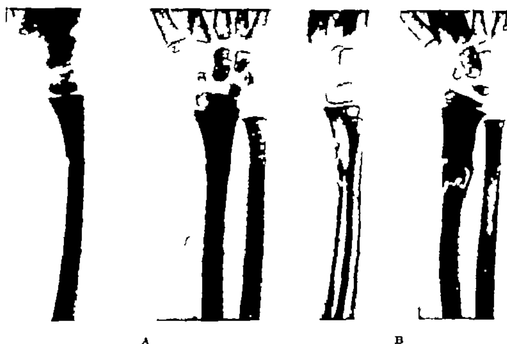
Fig. 88 Radiograph of the forearm showing chronic osteomyelitis of the shaft of the radius. Note the irregularity of the contour of the involucrum and the intact distal epiphysis. The elongated area of rarefaction in the middle third with the raised flap of involucrum at its proximal and outer extremity indicates an area from which a sequestrum has been removed. There is a thin line of periosteal new bone along the shaft of the ulna indicating periostitis.

of the onset of prominent clinical signs In some cases fracture initiates the onset of osteomyelitis. Thus radiographs of the long bones of children have shown green stick fractures when radiographed immediately after an injury but further radiographs of the site two or more weeks later have shown the typical signs of osteomyelitis (see Figs 86 A and B p 101) The earliest indications defy lithographic illustrations It consists of a localised area of decalcification usually near the extremity of the diaphysis

Gradually this becomes in the course of a week obvious as in Fig 87 A Note that the epiphysis appears to be spared A month later (see Fig 87 B) there is evidence of an involucrum erosion of the original shaft and the separation of dead fragments. The persistence of chronic infection is indicated by a massive irregular involucrum with perhaps a residual localised central abscess over which, during the phases of activity periosteal accretions of new bone may be seen

The early administration of such agents as sulphathiazole or penicillin may abort the process and lead to resolution the only radiographic changes detectable being at first some degree of localised osteoporosis followed by some increase in the density of this area and its surroundings In the chronic form, an irregular involucrum may be seen, as in Fig 88

In a few cases of Multiple Osteomyelitis I have found single well-defined areas of rarefaction in the lower end of the radius—these are probably aborted foci. *Goldstein*



A B

Fig. 88A. Radiograph of B.H., 28/4/47 showing a green-stick fracture of the lower third of the radius—the result of a fall.
Fig 88B. Radiograph of B.H., 23/5/47 showing osteomyelitis with separation of sequestrum t site of green-stick fracture.

and *Kurbangalejew* have illustrated *Brodie's* abscesses in the lower inner border of the ulna, and *Sutejew Utenkow* and *Zeillin* show a similar lesion due to the blastomycetes which healed with X radiation.

Horgan has illustrated a cortical abscess of the shaft of the ulna produced by Bacillus Typhosus The cortex shows a flattened cyst like elevation of a localised area of the periosteum which developed after trauma.

Huenekens and *Rigler* have illustrated destructive lesions about the epiphyseal lines which developed in a boy of 4 years of age simultaneously with the eruption of variola.

Hyperparathyroidism. The characteristic form of osteoporosis is shown in Fig 89

Tuberculosis. The area indicating the focus of infection in the early stage may not

show any evidence of internal structure but as the disease progresses the bones become more rarefied and frequently a denser shadow with an ill-defined periphery may be seen at the site of the original focus—this is a sequestrum and being shut off from the blood supply it is not subjected to the decalcifying action which is in progress. In these localised tubercular deposits no periosteal reaction may be seen, even when the erosion has extended to the periphery If however there is a general tuberculous osteomyelitis



Fig. 89 Hyperparathyroidism. Characteristic type of osteoporosis.





Fig 90. Radiograph showing tuberculous osteomyelitis of the shaft of the ulna and the fifth metacarpal on the one hand and of the proximal phalanx of the index finger on the other Note the more regular contour f the involucrum and compare with Fig 88.

of the shaft of the bone the periosteum is raised from the surface of the bone and new periosteal bone surrounds the shaft, the outline of which is gradually absorbed, and the radiographic appearance simulating tuberculous dactylitis is produced, as in Fig 90 The outline of the involucrum in tuberculous osteomyelitis is usually more regular than that seen in pyogenic osteomyelitis, and any sequestrum formed has an irregular ill-defined periphery and mushy coke-like structure. Tuberculous foci commencing near the epiphyseal line often extend into the epiphysis and involve the joint (see Fig 91). Other types of lesion which may occur are described on pp 71 and 72



Fig. 91. Tuberculous focus in ulna (23/3/41 29/4/41 16/12/41 10/2/42).



A B

Fig. 92A. Syphilitic osteomyelitis of ulnar shaft in a girl aged 8 years.
Fig. 92B. Same patient as Fig. 92A after anti-syphilitic medication.

Syphilis We have already indicated that in congenital syphilis the extremity of the diaphysis may show an irregular line of dense bone lying on a decalcified zone with increased density of a core of cancellous bone more proximal, and that areas of subperiosteal bone erosion near the extremity of the diaphyses may be present.



FIG 93. Sclerosing type of syphilis of ulna and radius.

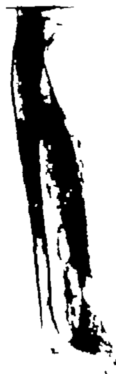


FIG 94 Syphilitic osteomyelitis of radius in adult aged 80 years.



FIG 95 Polycystic dysplasia. Note that bones apart from lesion are normal in character

After three months of age the most characteristic feature is the syphilitic osteoperiostitis indicated by increased thickening and density of the shafts of the bones. The increased density is not uniform, but irregular in its distribution. Later the shafts of the bones may show localised gummata which are indicated by marked localised spindle-

shaped thickening of the bones of increased density sometimes showing relatively small areas of central rarefaction (see Fig 160)

When the lesion is in the region of the epiphyseal line, the line becomes thicker and its borders, particularly the diaphyseal irregularly sclerosed as in Figs. 166 and 167

Probably the most characteristic and remarkable feature of the syphilitic bone lesion is the complete restoration to normal on efficient medication (see Figs. 92 A and B)

In certain cases in which natural healing of affected bones has been attempted the medulla may show areas in which the cancellous structure is obliterated by dense deposits of calcium rather like the fossils in limestone. The affected area of the shaft is increased in thickness but the periosteal border is smooth, though perhaps showing undulation according to the extent and regularity of the lesions (see Fig 93).

In the adult with neglected bone syphilis multiple gummata may be seen in one or more bones. Other bones may show extensive destructive erosion or irregular and massive periosteal accretions (see Fig 94)

Polycystic Dysplasia. Multilocular cyst-like changes may involve the whole of the bone, a segment or a portion of the cortex, see Figs 84 A and B 95 214 227

These lesions are laid down in early life and are gradually pushed into the shaft by the growth of bone at the metaphysis. They impair the stability of the bone and fracture may occur through them. They tend to contract and consolidate with age.

CHAPTER X

ELBOW JOINT AREA

OSSIFICATION

A RADIOGRAPH of the elbow of a normal child during the first year of life shows no epiphysis. Early in the second year the nucleus for the epiphysis of the capitellum appears on the expanded lower extremity of the humerus a little to the outer side of the mid line of the shaft. This continues to grow and by the fourth year it has reached the size of a pea. Towards the end of this year or the beginning of the fifth year another nucleus appears—that for the epiphysis of the head of the radius. This is accompanied, or soon followed, by the nucleus for the internal epicondyle. No other nucleus is seen until during the ninth year the nucleus for the external epicondyle appears, and this is followed during the tenth year by the nuclei for the trochlea (two or more) and the olecranon (two or more). The nuclei for the trochlea and the external epicondyle may be seen to fuse together after the fourteenth year the fused element unites with the capitellum and the combined epiphyses unite with the diaphysis after the sixteenth year and about this time the head of the radius and the epiphysis of the olecranon also join. The epiphysis usually last to unite is that of the internal epicondyle which fuses after the eighteenth year The diaphyseal extremities do not show the typical changes in infantile rickets or scurvy even when marked changes are present in the wrist, but in renal rickets of adolescence rachitic changes similar to those at the wrist involve the metaphyses of the bones forming the elbow as well. In infantile syphilis marked irregularity with evidence of disorganisation of the bony extremities may be present.

Congenital Deformities. Congenital deformities of the elbow joint elements are less frequent than in the more distal parts of the extremity They are frequently bilateral familial defects. The chief deformities met with in radiography of the part are those due to fusion of the epiphyses producing general bone ankylosis, fusion of the epiphyses or diaphyses of the upper end of the radius and ulna, subluxations and dislocation of the head of the radius, and, more rarely patella cubiti.

The radiographic appearance of the synostoses presents little difficulty in interpretation. The lesion may be bilateral, but in any case the two sides should be radiographed as symmetrically placed as possible This is particularly important when subluxation is suspected.

In cranio-cleido-dysostosis a familial dysostosis, the lateral humeral condyle may fail to develop and dislocation of the head of the radius occurs. The olecranon may persist without bony union to the ulna. In adult life these defects tend to show severe secondary changes with the formation of separate ossicles and the development of osteoarthritis It shows a familial distribution.

Fahlstrom has described and illustrated Familial Radio-ulnar Synostoses and *P Simon* has illustrated bilateral ankylosis of the elbow joint also bilateral congenital subluxation of the head of the radius In *Coppa's* paper are to be found radiographs showing fusion of the upper epiphyses of the radius and ulna, while *Aitken*[1] has reported cases showing bilateral fusion of the elbows and others showing bilateral dislocation of the elbows. Radiographic appearances of the elbow joint simulating these congenital deformities may be shown as the result of old injuries

A more striking radiographic appearance is that of Patella Cubiti which may be

present as a bilateral or unilateral familial defect. This condition has been illustrated and described by *Gunn*. Other observers including *Cunningham Eisler Fiedler Katz* and *Kienböck*, have also described the condition. Radiographs show a large sesamoid bone occupying a position on the dorsum of the elbow which simulates the appearance of the patella, as in Fig 96, A. *Köhler* illustrates separate ossicles lying against the internal epicondyle—*in one case bilateral. The olecranon on both sides may appear* as a separate bone with a cartilaginous gap of $\frac{1}{16}$th inch between it and the upper end of the ulna.

The olecranon fossa of the humerus shows a great variation in density in different individuals. Many examples are met with in which the radiographs show that the bone is perforated at this point, as in certain animals (pigs, etc.) The condition is frequently bilateral, and, associated with the foramen, a loose body is occasionally seen.

Hirsch[1] has demonstrated this foramen in gorillas, ancient Egyptians and moderns. He says it is not found before the age of 6 that it is more common in females, and larger on the left side.

H R and *B D Senturia* have described and illustrated a patient, aged 36 years, who had arthrodysplasia associated with dystrophy of the nails and congenital absence of patellæ.

A small spur may be seen on the antero-medial border of the lower third of the humerus shaft. This is the Supracondylar Process. It is directed distally (very rarely the distal extremity joins with the shaft and forms a foramen, as in the lower animals). In man a fibrous band joins it to the medial border of the humerus, and through the foramen so formed, the median nerve or the brachial artery or both, may pass.

A small spur is sometimes seen projecting from the superior extremity of the dorsum of the ulna at the site of insertion of the triceps, the so-called Processus Anguli Olecrani. Small detached ossicles are occasionally met with at this site.

Injuries to the Elbow Joint. Injuries to the elbow joint in childhood may be difficult to interpret from the radiograph owing to the disposition of the epiphyses and to the

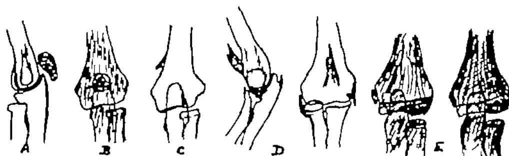


FIG 96. Abnormalities of the elbow joint area.

A. Patella cubiti.
B. Perforation of the olecranon fossa associated with a loose body.
C. Supracondylar process.
D. Spurs on the humerus, radius and ulna following dislocation of the elbow joint.
E. Osteochondritis capitulum humeri.

fact that the patient fixes the joint so that complete extension the most valuable radiographic position, cannot be obtained. Symmetrically taken radiographs of both sides need to be carefully compared. No other radiograph or diagram will be so likely to indicate a departure from the normal.

Complete separation of the internal epicondyle, the capitellum, or fragments of the articular surface into the cavity of the joint may occur and the relative positions may

alter considerably on movement of the joint *Walker* illustrates such a case, and *Belot Lepennetier* and *Pellizza* have excellent illustrations showing normal and injured elbow joints.

Fractures of the lower end of the humerus during childhood may have a sequel during adult life by the development of ulnar nerve lesions Following such a fracture there may be no localised symptoms for many years. *Miller* has described cases in which symptoms of nerve involvement did not appear in one case for 30 years in another 23 years, and in others 18 and 15 years, respectively His radiographs illustrate old fractures involving the capitellum In his opinion, injuries during the third to fifth year which result in separation of the external condyle and its displacement forward and laterally with the fracture surface twisted outward usually result in non-union of the fracture and interference with the growth of the bone on that side to such an extent that Cubitus Valgus gradually develops. The ulnar nerve is displaced from its shallow bed by the olecranon becoming impinged against the median condyle, and the displaced nerve is then subjected as the arm is flexed or rotated, to stretching and trauma from which it would have been protected in its normal position.

Signs of nerve involvement may commence within 5 years of the injury but in the majority of cases there is freedom from symptoms for 20 to 30 years.

The author has seen cases of fracture of the lower end of the humerus in children in which the damaged bone has undergone irregular absorption and bone growth has been considerably interfered with. The radiographic appearances throughout 3 or 4 years have suggested a traumatic osteochondritis which may be confused with tuberculosis of the elbow joint owing to the progressive deformity which develops.

Heiss took radiographs of the joints of 150 athletes who were engaged in Olympic games, and found spur formation at the articular margins, free bone formations near the joints and foreign bodies within the joints in those athletes using chiefly certain parts of the body such as the arm

Meiss has shown ossification of the origin of the brachialis anticus forming a spur in front of the humerus just above the elbow joint in riveters using compressed-air drills. The condition of Epicondylitis, indicated on the radiograph by small spurs of new bone on the humerus, particularly around the external epicondyle pointing distally is a condition which develops in certain tradesmen, who subject the elbow to frequent strain such as shoemakers. Somewhat similar changes may be seen in the radiographs of patients suffering from Tennis Elbow *Blecher Jungmann Köhler* and *Sourdat* have also illustrated these appearances.

Calcification in the Epicondylar Bursa may develop after trauma. Relatively trivial trauma may cause relatively rapid distension of the bursa which may first attract attention by its size for it may be painless. Olecranon Bursitis is said to be common in Gout. *A B Hamilton* illustrates the lesion in a man of 42 years of age who received an injury to the part 11 months previously Radiographs showed a deposit of calcium on a plane with the joint space from the upper border of the lateral condyle to near the head of the radius. No sign of the calcium could be seen in radiographs taken after five weeks of rest.

Para-articular and parosteal calcification and ossification has been seen to follow damage or disease of the cervical cord or of the central or peripheral nervous system and records of such have been published by the author [39] Repeated slight injuries to the elbow joint in the Hæmophilic may result in expansion and compression of the radial head, irregularity of the articular surfaces of the joint and the appearance of small rounded areas of cancellous destruction in the subarticular bone

Myositis Ossificans. The most serious lesion to develop in the neighbourhood of

common as in the knee joint but single and multiple loose bodies have been seen, more often following injury or signs of Osteochondritis. The olecranon fossa is perhaps the most common site for the loose body Cases have been seen in which the antero-posterior radiographs have suggested that the loose body was in the olecranon fossa, but careful lateral and oblique radiographs have shown them to be on the anterior aspect of the humerus A careful inspection of this area should be made in all suspicious cases. In some cases lipping of the margins of the olecranon may produce the appearance of a loose body

In Osteochondromatosis numerous loose bodies may be shown, and radiographs taken at intervals show that some become decalcified.

H T Jones has illustrated many examples of this condition, and he considers that osteochondromatosis is of the nature of a benign neoplasm.

Kadrnka and *Naz* have illustrated a case with a large calcareous deposit lying against the postero-lateral surface of the lower end of the humerus in a bursa beneath the triceps.

Fig. 100. Chondromatosis (see also Figs. 43, 120, 219).

Tumours. Practically every type of tumour has been seen in the neighbourhood of the elbow joint, and the reader is referred to the chapter describing the radiographic appearance of bone tumours An interesting symmetrical concave paring of the middle third of the shaft of the humerus due to an Extramedullary Capillary Angioma which led to a spontaneous fracture is recorded by *Ballance* There was a history that the arm had been crushed between buffers 24 years before.

It would, however be well to remember that fractures of the ulna and radius may occur in children without their knowledge, and the first indication that this has occurred may be the discovery of a hard tumour in the forearm. The radiographic appearance should enable a correct diagnosis to be made, but one such case was referred to the author for confirmation prior to amputation of the limb—the clinical and radiographic characters of the lesion having been interpreted as a sarcoma—an error which is liable to recur owing to the use of X ray apparatus by men who have not had a sufficient training in the interpretation of radiographs.

Fig 98 shows a large tumour with the typical appearance of a *Lipoma overlying the middle third of the humerus* Note that it is less dense than the other soft tissues surrounding it.

The growth of the bones of the forearm may be seriously interfered with in cases of multiple chondromata. Inequality in development will lead to dislocation at the elbow joint as in Fig 99

General Skeletal Pathology Changes seen in the shafts of the ulna, radius and humerus, characteristic of Osteomyelitis, Osteomalacia Polycystic Dysplasia, Polyostotic Fibrous Dysplasia, Hyperparathyroidism, Osteitis Deformans, Osteogenesis Imperfecta, Albers-Schonberg's Disease, etc as well as of chronic inflammatory and neoplastic disease are discussed in other chapters

Multiple Chondromata (Chondromatosis) The distribution of the lesions in this condition is well shown in Fig 100 It will be seen that the bones at the elbow joint do not show the extensive changes which are present in the wrist and shoulder joints

Osteomyelitis As the result of osteomyelitis in the young person before growth is



Fig 101A. Normal humerus



Fig 101B Opposite humerus of same patient stunted in growth by infantile osteomyelitis.

completed, considerable stunting may be produced. Compare the relative sizes of the two humeri in Figs. 101 A and B The other changes which may develop are described in other sites.

CHAPTER VI

THE SHOULDER

OSSIFICATION

The Humerus at birth has a cone shaped *proximal extremity with the apex of the* cone a little to the medial side of the middle line of the shaft. Opposed to the medial face of this cone the nucleus of the epiphysis for the medial surface of the head of the humerus may be seen, though more commonly this does not appear until about the fourth to sixth month of life This single nucleus grows and becomes ovoid in shape but it is not until the second year of life that its neighbouring nucleus for the great tuberosity appears on the lateral aspect of the cone though occasionally this is seen during the first year of life A further nucleus for the lesser tuberosity can sometimes be demonstrated during the fifth year of life It is rare to see all the three nuclei on one plate but from time to time radiographs are obtained which show them—in the case of Chondro-osteodystrophy which I [11] published, three distinct rounded but spotted epiphyses were shown in the upper end of the humerus During the fifth year of life the nuclei for the tuberosities fuse and at the age of 12 to 14 this fused nucleus unites with the epiphysis for the head. The upper end of the diaphysis may still appear on the radiograph to have a triangular proximal extremity but in some cases the undulating metaphyseal faces of the diaphysis and epiphysis result in a very irregular epiphyseal line on the radiograph.

Owing to this undulation of the broad surface and the fact that in the radiograph shadows of all segments are superimposed on one another what appears to be the definite epiphyseal line may have other irregular transverse fissures distal to it—these have led to the erroneous diagnosis of fracture

The Scapula The scapula commences to ossify during the eighth week of foetal life and its adult form is made up by the addition of some eight bony nuclei The nucleus *for the coracoid may be visible at birth, and union with the main body is completed* about the fifteenth year Ossification of the other nuclei commences about the tenth year the first being a sub-coracoid nucleus which eventually enters into the construction of the base of the coracoid process and the upper part of the glenoid At about 15 years of age three or more nuclei appear at the extremity of the acromial process and, soon after this, a nucleus appears at the inferior angle of the scapula, and, later one for the *vertebral border A nucleus also appears in the lower part of the rim of the glenoid* cavity about puberty this forms the rim which deepens the adult glenoid.

The radiographic demonstration of multiple nuclei for the end of the acromion *may lead to the interpretation of fracture It is* not unusual to find on dissection that one of the nuclei has formed a small bone which has not united with the main process (the os acromiale) but it is rare to demonstrate this on the routine radiograph. A small epiphyseal nucleus also develops at the free extremity of the coracoid process. By the twenty fifth year of life all the epiphyses have united with the main body A small ossicle may be seen at the upper surface of the glenoid as in the acetabulum. It has been seen in girls of 10–12 years, bilateral Another small ununited ossicle may be seen at the lower extremity of the glenoid and another on the medial aspect of the coracoid process. In some cases the epiphysis for the inferior angle of the scapula does not fuse with the body Its appearance may suggest fracture.

The Clavicle. The clavicle is the first bone in the body to show ossification It

develops from three centres Two primary centres, medial and lateral for the body appear in the fifth to sixth week of fœtal life and fuse about the seventh week The third nucleus, which develops in the epiphysis of the sternal extremity does not appear until about the sixteenth to twentieth year of life and it unites about 25 years of age: a feature which may help to decide age The line of contact between the radiographic film and the soft tissues which runs parallel with the superior border of the clavicle is due to secondary radiation It is sometimes mistaken for evidence of periostitis

Fig 102 shows that full movement of the shoulder joint does not occur till the arm is erect and illustrates graphically the fallacy of the traditional teaching that movement



Fig 102. Tracings from *Lockhart's* radiographs illustrating the degree of movement in the shoulder joint and the activity of the deltoid muscle between the horizontal and the vertical positions of the arm. Note the position of the anatomical neck—one-third of the way up the glenoid cavity with the arm in the dependent position.

of the shoulder joint is exhausted by raising the arm to the horizontal subsequent vertical elevation being secured by scapulo-thoracic rotation alone This erroneous teaching is perpetuated in certain X ray atlases.

The fact that the spine of the scapula is in line with the humeral shaft in full abduction is a ready guide to the clinician in estimation of full shoulder joint abduction. At this point it is opportune to insist, firstly upon the variation in the radiographic appearances obtained when the shoulder is taken with the patient prone supine, and standing and, secondly upon the necessity for caution on the part of the clinician not to associate an erect patient with a radiograph taken in the recumbent position.

Irregularities of the Clavicle A small ovoid foramen about 1 mm. long may be shown in the clavicle near the junction of its middle and outer thirds—the nutrient foramen It receives a lateral branch of the supraclavicular nerve.

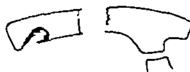


Fig. 103. Irregularities in development in medial and lateral thirds of the clavicle

Near to the sternal end, on its inferior surface, and at the site of the attachment of the rhomboid ligament a rough excavation of the bone may be seen as a bilateral lesion. It should not be mistaken for a localised inflammatory erosion Another bilateral developmental deformity which may be seen in conjunction with the above is a bony process from the inferior margin of the outer third which is directed to a similar process on the coracoid—the opposing surfaces appear to be facetted, they occupy the position of the conoid and trapezoid ligaments (see Fig 103). Ossification of these ligaments is seen and the joint like appearance of the anomaly cited in the previous

sentence may be produced by a pseudo-arthrosis developing in such ossified ligaments at the site of strain.

A suprasternal ossicle may be seen on each side opposite the sternal end of the clavicle

Calcification of the coraco-clavicular bursa has been described and illustrated by *H J McCurrick* The deposit, larger than a hen's egg, appeared to lie between the clavicle above and medially and the coracoid process below and laterally The patient, a man aged 51 gave the history of a severe injury to the shoulder from a fall.

Irregularities in the Structure of the Head of the Humerus. In the head of the humerus areas of radio-transparency of various sizes—sometimes with fairly well-defined margins—are frequently seen unassociated with bone disease (see Fig 104 B)

In some cases large single areas are shown, which appear to be devoid of cancellous

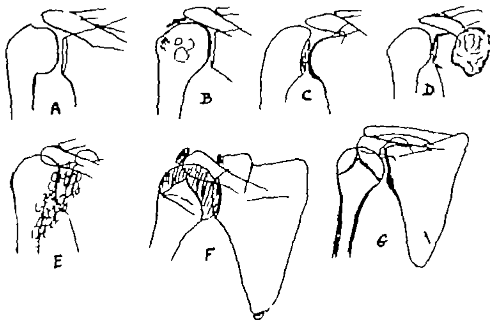


Fig 104. Tracings of radiographs of the shoulder joint.

A. Humerus varus.
B. Areas of rarefaction in the head of the humerus and deposits of calcium in the tendon of the supraspinatus.
C. Congenital deformity of the shoulder joint The articular surface of the humerus is concave the glenoid articular surface is convex.
D. Osteoclastoma of the coracoid.
E. Osteochondromatosis of the shoulder joint.
F Epiphyses in the region of the shoulder
G. Congenital deformity of the glenoid fossa (bilateral).

bone and which may be misinterpreted as fibrocystic disease or early tumour formation or tuberculous caries. Such areas may develop as the result of trauma or following immobilisation for fracture of the humeral shaft they are usually present in atrophic conditions of the bone as in old age They may be distinguished from pathological lesions other than secondary carcinoma by the absence of any evidence of reaction Similar areas are seen in association with osteoarthritis these are degenerative areas with cancellous destruction similar to those seen in senile bones *Fisher* has suggested that these areas are due to amœbic invasion, while *Thompson* considers that helminthes

are responsible but there is little or no histological evidence to support these theories. Examination of sections of a large number of normal humeri revealed these areas of various sizes in all.

Single or multiple rounded or ovoid islands of condensed bone may be shown in the cancellous tissue of the head—multiple areas indicate generalised **Osteopoikilie.**

Congenital Abnormalities. The most outstanding congenital deformity of the shoulder is that known by the terms undescended scapula, elevated or congenital high shoulder—Sprengel's deformity. The radiographs of this condition show elevation of the affected scapula, its superior angle in most cases being on a higher plane than the neck of the first rib. Little or no deformity of outline of the scapula or the cervical spine may be seen. In other cases one has noticed failure only of fusion of the laminæ of the



FIG 103. Sprengel's shoulder. Note the large oblong suprascapula which is opposed to the oblique vertebral border of the elevated left scapula and replaces the left laminæ of the sixth and seventh cervical vertebræ.

sixth and seventh cervical vertebræ with a little irregularity of the laminæ on the affected side. In one of my cases the vertebral border was in apposition with the lower five cervical vertebræ. Defects in the development of one or more of the upper dorsal vertebræ may also be seen. More commonly the superior vertebral angle of the scapula appears to be cut off, so that the upper third of the vertebral border is at an angle with the lower two-thirds. From the angle produced by the superior and inferior parts of the vertebral border an additional bone, the suprascapula, runs in an oblique direction to the sixth or seventh cervical or first dorsal spine. This bone may be only a narrow strip which, with the oblique superior vertebral border gives the impression that it is a strip which has been torn from the border, or it may be a large, thin, oblong-shaped plate of bone closely applied to the oblique vertebral border inferiorly and replacing the laminæ on that side and entering into the formation of the spines of the sixth and seventh cervical and first dorsal as in Fig. 105.

The deformity is sometimes associated with paraplegia, as in the case illustrated by *Critchley*

In some cases of Progressive Muscular Dystrophy the shafts of the long bones may be very slender It has been recorded as an external progressive atrophy It is seen in some cases of long continued paralysis : an even greater attenuation of the bones is seen in the tubular bones of the lower extremity in some cases of Osteogenesis Imperfecta (see p. 171–2)



FIG. 106. Left Sprengel's shoulder Note defect in neural arch of upper dorsal vertebra.

Agenesis of the scapula is recorded by *R Ornstein* and *W Müller* in a girl of 10 years. It was associated with periodic suppuration and discharge (see Fig 101 B)

Another striking congenital deformity of the shoulder shown on the radiograph is the condition in which the articular face of the head of the humerus is concave and the articular surface of the glenoid is convex, as shown in Fig 104 C, which is a drawing of the radiograph of a man, 30 years of age *H Lewin* has described and illustrated a somewhat similar radiograph of the shoulder of a girl, 20 years of age These anatomical features were produced in a rabbit by *Wachter* who opened the shoulder joint, removed the articular cartilage and altered the muscular attachments. This change in the relationship to the ball and cup lends support to the theory of *Fick* which implies that the form depends upon the position of the attachments working the joint (see Fig 107). In three cases two women and one girl, aged 9 years radiographs have shown a bilateral defect in the formation of the glenoid, the latter being flat and having no lip to the lower half. The radiographic appearance suggests failure of development of the epiphysis for the lower rim of the glenoid (see Fig 104 G). The deformity was associated with webbing of the axillæ and marked limitation of abduction. The conoid and trapezoid ligaments may be replaced by a bony bridge uniting the clavicle with the coracoid process *Heupke* also *Giongo* have illustrated examples of these deformities. A joint may be formed

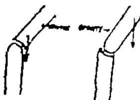


FIG. 107

between bony projections at this site. The angle formed by the line through the centre of the articular surface of the head and the axis of the shaft of the humerus in the normal is about 140°. Examples are met with in which the radiographs show marked diminution of the angle even below 100°. This is the condition of **humerus varus**. In radiographs of the condition the great tuberosity may appear to be on a higher plane than the superior articular surface of the head, and the width of the head from a point opposite the middle of the glenoid to the lateral border of the humerus is less than the normal. Some authorities are inclined to the view that this is a congenital defect but, like coxa vara, it might be due to bending of the bone during the acute phase of scurvy or rickets of infancy as the upper end of the diaphysis of the humerus shows similar changes in these conditions to those seen in the lower end of the radius, and pressure applied to this disorganised bone may result in the deformity of humerus varus. The bilateral appearance of this deformity supports this theory. *Seifert* uses radiographs illustrating bilateral humerus varus in an otherwise healthy man. *Vicotra*[2] has reported three cases, one in a normal adolescent one in a cretin, and one in a subject of achondroplasia; he suggests that it may be due to breaking down of a monarticular cyst.

Barlow pointed out that in scurvy towards the later months of the infant's first year of life as a result of subperiosteal hæmorrhage following mild trauma the diaphysis may be displaced outwards from the epiphysis through a tear in the expanded periosteum. The lesion is not uncommonly bilateral. Radiographs taken soon after the displacement show the upper end of the humerus displaced laterally some distance from the scapula, the epiphysis with its growth cartilage and the densely calcified juxta epiphyseal end of the diaphysis preserving its normal relationship with the glenoid. Radiographs taken after a fortnight's interval during which vitamin C has been administered, will show a deposition of calcium in the gap between the diaphysis and epiphysis and during the following fortnight this will be sufficiently dense and organised to indicate that it represents an organising hæmatoma which envelops most of the shaft. Its upper medial border will not envelop the epiphysis but show the relationship to it which the normal diaphysis does, *i.e.* it will be separated by a linear gap—the growth cartilage. During the remaining months of the year following the displacement the upper third of the diaphysis will be gradually pared down, for the ossified hæmatoma has now taken its place and by the end of the year the humeral diaphysis will present the angulated appearance of an old healed fracture about the junction of the middle and upper one third. Examples of such diaphyseal displacements may be seen at the lower end of the femur and tibia and at the costochondral junctions. An excellent description of these lesions, with illustrations, is given by *W. Scott*.

Similar displacements may occur in the first three months of life and in **Infantile Syphilis**.

In **Renal Rickets** the metaphysis may be very thick and so disorganised as to permit of displacement of the epiphysis. The most marked thickening of the metaphysis illustrated in the literature is to be seen in the paper by *Tebrügge* in which only thin peripheral triangular areas of bone represent the epiphysis at the upper end of the humerus in a boy of 18 years. He regarded the condition as being due to endocrine disorder but one has seen thickening of the metaphysis in renal rickets of such a degree as to warrant the consideration of this disease in the differential diagnosis.

Bilateral or unilateral defects of varying degree are to be seen in the clavicle in **Cleido-cranio Dysostosis**. The defects in the majority of cases are found at the sternal end, but examples have been illustrated in which the acromial end or even the whole bone has been missing. These defects in the clavicle may be mistaken for old fractures. In one case compensation successfully claimed on one occasion failed at another when

the nature of the lesion was detected. Associated with these defects one sees other defects in the skull and femoral necks and variations in the shape of the long bones of the hands and feet such as are described in an earlier chapter These features have been seen in cases of progeria.

Greig considers that all the bones which are developed in membranes may show defects in association with the clavicle The radiographic appearance of these defects in the clavicle has been interpreted as pathological fractures The condition was described by *Marie* and *Sainton* in 1897 A review of the literature with illustrations of unilateral and bilateral cases is given by *Fitchet*. See General Discussion, page 577

Bursæ occur in the neighbourhood of the shoulder joint and radiographs showing calcareous deposits in the subdeltoid and subacromial bursa have been met with. The appearance of these calcareous deposits lying as they generally do above and parallel to the upper surface of the head of the humerus, suggests loose bodies within the shoulder joint Somewhat similar shadows are seen in the radiographs of shoulder joints which have been dislocated or subjected to severe trauma a few weeks or months previously (no sign of calcium may be seen for 2 or more weeks after the injury), but in these cases the shadows are usually due to detached bone fragments or to ossification of portions of the injured capsule or to deposits of calcium in the tendinous insertion of the supraspinatus and the infraspinatus (see Fig 108) Radiographs, taken at intervals of shoulders showing these collections of calcium, prove that such deposits may become reabsorbed. In some cases the calcium deposit can be extracted with a syringe The pain is said to be reduced by X radiation therapy The deposits may be bilateral but pain may be present only on one side



FIG. 108. *Radiograph showing a collection of calcareous* deposits in the supraspinatus tendon following trauma.

Stereoscopic radiographs of these cases will often give valuable assistance in the location and nature of the abnormal shadows Radiographs taken soon after a dislocation has been reduced may show no departure from the normal appearance but very frequently after an interval of several months, shadows of irregular spurs of new bone formation are seen around the upper end of the shaft of the humerus and the neck of the scapula, or shadows suggesting the deposits of calcium previously described.

Localised impaction of the humeral head against the rim of the glenoid on which it is displaced has been seen in cases of Electric Shock. The antero-posterior radiograph shows the glenoid and humeral head apparently undamaged but without the space required by the articular cartilage A small quadrilateral shadow with fairly well defined borders and of slightly greater density in the subarticular area is the depressed fragment. The dislocation and depression can be shown by lateral radiographs (see Fig 109)

Very considerable damage may be sustained in the shoulder during convulsive therapy The humeral head may be comminuted.

In a large number of shoulders which have become painful after a fall during which a Colles fracture may have been produced, the radiograph does not show any

Albee counted sixty-four joint mice in the shoulder of a man aged 33, who gave a history of a severe injury 18 years before. The radiograph shows a large collection of these loose ovoid bodies.

Kolliker considers that the bodies are formed from the synovial membrane and not from the articular cartilage as is the case in Osteochondritis Dissecans and Osteoarthritis.

Hagemann described a case of osteochondromatosis of the shoulder which was associated with loose bodies in the subcoracoid bursa and the synovial sheath of the long head of the biceps.

Hugh T. Jones reviewed the literature of the condition and illustrates a number of cases. Further illustrations are to be found in the papers by *Solomon* and *Gilbert, Colonna,* and *St. Kartal*.

Tuberculosis. The earliest radiographic sign of tuberculosis in the shoulder joint is frequently to be seen as a small area of erosion of the superior aspect of the neck of



FIG. 115. Radiograph showing early tuberculous caries of the head of the humerus. Note the small excavation on the superior surface of the neck of the humerus, and alteration in the bone trabeculæ in this neighbourhood. Radiographs of this shoulder taken two years later showed marked erosion and atrophy of the humeral head in spite of fixation and open-air treatment.

the humerus, *i.e.* between the lateral aspect of the articular surface and the medial aspect of the great tuberosity as shown in Fig. 115.

In others the first radiographic sign has been a *linear* subperiosteal secretion of new bone which might be mistaken for a simple periostitis of the upper end of the shaft. This may be associated with a localised area of rarefaction.

As the lesion progresses the articular surfaces lose their sharpness of outline and the bone becomes less dense, the head of the humerus gradually loses its regular rounded appearance and becomes smaller, its borders ill-defined and its trabeculæ coarse and irregular with areas in which the cancellous bone appears to be destroyed. In some cases the humeral head may appear to contain a Multilocular Cyst. For description of other types see pp. 11–12.

Syphilitic Arthritis of the shoulder joint in the adolescent is suggested by erosion in association with irregular sclerosis of the bone in the metaphyseal area.

The clavicle is one of the commonest sites of election for syphilitic osteitis. This may take the form of (*a*) irregular osteo periostitis as in Fig. 92A, (*b*) irregular thickening and

prints obtained in this way are that the details of the dense bony structures can be preserved along with those of the outlines of the soft tissues, and a relief picture of the structures is so obtained, whereas with the ordinary straight print from a radiograph the details of the soft tissues or of the bones, are lost because of the marked contrast in the densities

A Charcot's shoulder joint in a woman of 47 which is illustrated and described by *Claessen* shows complete absorption of the head of the humerus and the neck of the scapula. Attention was suddenly focussed on the joint by a spontaneous fracture. He points out the slight brief symptoms which were associated with enormous bone destruction.

Bone Dystrophies. Evidence of bone dystrophies may be seen in radiographs of the shoulder joint

In **Chondro-osteo-dystrophy** during infancy the epiphyses show multiple bony nuclei and considerable deformity may later develop (see pp 502–70) In chalky bones



FIG 114 Chalky bones (Albers-Schönberg's disease)

(*Albers-Schonberg*) the bones are increased in density and lacking in the normal architecture (see Fig 114)

Osteochondromatosis. A shoulder exhibiting some of the features of a Charcot's joint may on radiographic examination show multiple round or ovoid loose bodies—the condition of osteochondromatosis (see Fig 104 E) Investigation of these cases has proved that only a percentage of the loose bodies present show ossification and therefore cast a shadow on the radiograph. If such joints are examined repeatedly after long periods they show that in some cases these bodies become absorbed. There is frequently a history of severe trauma in these cases and it has been suggested that the loose body formation is induced in this way—other authorities are inclined to the belief that this is of the nature of a benign tumour from the synovial membrane as some of the loose bodies are attached to this membrane by a pedicle

(see Fig. 118). With large cysts the thinned cortex of the shaft is bulged as if being distended by the pressure of fluid within the cyst. The opening and sc such a cyst and insertion of a small piece of bone has been found by a number of to lead to fairly rapid consolidation—this practice may prevent the possibility of logical fracture with resulting deformity or even non union which has been



Fig. 117B. After sulphathiazole and anti-syphilitic medication.



Fig. 118. Radiograph of the shoulder of a boy aged 16 years showing a cystic tumour of the upper diaphysis of the humerus. Histological examination sugges clot.

sclerosis as in Fig 93 or (c) osteoporosis with complete osteolysis of all or part of the bone as in Fig 116 and (d) multiple gummata

Localised periosteal thickening associated with erosion of the cortex and changes in the cancellous pattern, as in Fig 117 A has aroused suspicion of Ewing s sarcoma



Fig 116. Radiograph of upper half of humerus showing an ununited fracture in a case of osteoporosis due to syphilitic osteitis.



Fig. 117A. Syphilitic periostitis mistaken for Ewing s sarcoma.

It showed response to sulphathiazole and completely resolved with anti syphilitic medication (see Fig 117 B)

Tumours. The commonest benign lesion of the upper third of the humerus is the **Simple Cyst,** and it is usually discovered as the result of a radiographic examination following an injury in this region—the injury may have resulted in a fracture through the cyst As a result of the fracture of the wall of the cyst healing may occur and complete consolidation of the affected bone result. From time to time one meets with examples of these bone cysts which have undergone complete calcification. If a radiograph is made for any reason before the bone fractures the cyst will be shown as an ovoid area of cancellous destruction—its borders may be and usually are fairly well defined, but occasionally only coarse open cancellous trabeculation throughout an area of the bone may be present and this may give rise to the suspicion of early neoplasm

tumour general osteoporosis of the humeral shaft This may have been due to disuse following a *fracture which occurred* as the result of a slight trauma a week or so before the radiograph was taken. The inner wall of the tumour had been destroyed and the tumour tissue was invading the soft tissues of the limb The limb was amputated and the patient *for over 8 years has shown no sign of recurrence* *Stewart* regards the tumour as only of local malignancy and amenable to local operative treatment or radiation therapy

In the course of investigation of this area one has met with examples of these simple giant-cell tumours presenting similar radiographic appearances in the acromion coracoid, axillary border of the scapula, and outer end of the clavicle

Lockrid Herendeen Le Wald,[2] *Evans* and *Leucutia* have illustrated with radiographs giant-cell tumours before and after treatment with X radiation and have shown that the tumour diminishes in size and that there is consolidation of the bone. *Simmons* found eight giant-cell tumours in the humerus in a group of 116 cases which he investigated. He is of the opinion that the tumour may change its character and become an osteogenic sarcoma but in no instance in the series were metastases discovered

Chondromata and **Osteomata** of the bone in this neighbourhood are frequently associated with similar tumours in other parts of the skeleton **Osteomata** of the multiple exostosis type may grow to a very large size and seriously affect the movements of the limb (see Fig 119) Radiographically they are distinguished from other tumours by the affected bone showing expansion at the base of the tumour into which the trabeculations of the shaft pass uninterruptedly The main mass of the exostosis is constructed of a more open and coarse cancellous trabeculation and its free periphery may show a dense thickened woolly margin due to sclerosis beneath the cartilaginous cap which many of the exostoses possess There is no periosteal reaction or any evidence of bone erosion. The expanded portion of the shaft may show a coarser trabeculation similar to the construction of the exostosis but the trabeculæ are well defined and show no evidence of destruction.



FIG. 119 Osteochondroma of humerus.

The radiographic appearance of **Chondromata** varies. They may cause little apparent destruction of the bone but usually the tumour contains some ill-defined *calcium deposits* which often give a clue to its nature Further the presence of chondromata in any other site will help to clinch the diagnosis (see Fig 120).

The shoulder is a fairly common site for this tumour and it is perhaps the commonest site for chondromata to undergo sarcomatous changes **Chondrosarcomata** are rapidly growing tumours, and should always be considered as a possible diagnosis when a chondroma during middle age begins to grow rapidly *J H Sheldon* and *Hirsch* have illustrated cases of this nature

Major describing 181 lesions of the upper end of the humerus, classified these as Sarcoma 30 Cyst 32 Exostosis 22, Metastasis 15 Giant-celled Tumour 9 Multiple Myeloma 6 Periostitis 6 Chondroma 2, Ewing's Tumour (Endothelial Myeloma) 2 Myositis 1

Anderson, analysing lesions in the clavicle found Metastatic Carcinoma 16, Multiple Myeloma 8 Periostitis 7 Bone Cyst 4 Ewing's Tumour 4 Exostosis 2, and one each of Chondroma, Giant-cell Tumour Chondroblastoma, Osteogenic Sarcoma, and Sclerosing Sarcoma

Cyst like changes in the bone which present a radiographic appearance similar to the simple cyst may be due to Polyostotic Fibrous Dysplasia, Polycystic Dysplasia, Myxoma Chondroma or Parathyroid Tumour In the latter condition the cyst formation in the humerus is associated with general osteoporosis of the skeleton, the formation of other cysts and changes which give a characteristic radiographic appearance

Crooks has illustrated a large cyst like structure the shape and size of a duck's egg at the outer end of the clavicle in a girl 4 years of age. This was due to a myeloma; good recovery and function followed excision and bone graft.

The radiographic appearance suggesting a multilocular cyst of the bone may be due to the localised form of polycystic dysplasia, osteoclastoma (myeloid sarcoma), chondromatous giant-celled tumour plasmocytoma and hydatid cyst; it may be impossible to distinguish between these from the radiograph, but, fortunately the distinction is an academic one—the same local treatment being indicated in all, *i.e.*, X Radiation in the first instance or local resection.

The author has drawn attention to a multilocular cystic tumour illustrated by *Geschickter* and *Copeland*. It was said to have the histological features of chondrosarcoma, but its subsequent history indicated simplicity

Codman[1] in his paper on Epiphyseal Chondromatous Giant-cell Tumours of the upper end of the humerus states that the tumour appears in the region of the great tuberosity; its upper extremity appears to be limited by the epiphyseal line so that it does not reach the joint surface as in other sites of giant-cell tumour the characteristic trabeculations seen in this tumour in other sites are replaced by areas of rarefaction having a blurred outline. *Kolodny*[1] describes the trabeculation of the giant-cell tumour in this site as being usually of a more delicate structure, the bone appearing honeycombed.

The fact is that one tumour will answer Codman's description, another showing the same histological features *Kolodny's* while another would not be accurately described by either The radiographic appearances are dependent upon the rate of growth of the tumour and the age and resistance of the patient's tissues. In young children, the *tumours tend to appear as unilocular cysts in older people, the multilocular appearance* is more common.

The age of the patient, the fusion of the epiphyses and the time at which the tumour is first radiographed have a bearing on the appearance of invasion of the epiphysis. If the patient is young and the epiphyses have not fused, the probability is that the upper limits of the tumour will be the epiphyseal line but if the tumour is not discovered until after the epiphysis has united radiographs may show that the destruction of cancellous bone has extended to the articular surface, as in other sites. In the slow growing giant-cell tumour the compact bone of the shaft immediately distal to the tumour is thickened and sclerosed particularly on its outer side.

Stewart has described and illustrated the radiographs and microscopic appearances of a Plasmocytoma of the upper third of the humeral shaft in a man of 31 The radiographs show in addition to the multilocular cyst like appearance at the site of the

but the clinical evidence should guard one from such an error In these cases the amount of bony change is usually great in proportion to the tumour of the soft tissues

The existence of **Endosteal Sarcomata** is frequently indicated by a spontaneous fracture when the radiograph will show central destruction with erosion of the compact bone at the site of the tumour Erosion of bone continues and further radiographs after an interval will show a progressive destructive lesion.

The radiographic characters of a growth are altered by X radiation So clearly defined and regularly ossified may a sarcoma become after X-radiation that its malignant character may be masked. Radiation given before diagnosis is almost as capable of defeating the clinician as morphia given before diagnosis in the case of appendicitis or other acute abdominal condition.

Metastases. The shaft and upper end of the humerus like the upper end of the femur is a common site for the development of metastases of malignant disease It should be suspected in spontaneous fracture (see Fig 121) *Jall* found metastases



FIG. 121 Spontaneous fracture through secondary carcinoma of humerus (A) 21/8/37 immediately after injury (B) 10/12/37

present in the head of the humerus in 7·0 per cent of eighty-eight cases. As in the case of endosteal sarcomata the existence of such metastases may be brought to light by a spontaneous fracture The radiograph will show an appearance suggesting that the bone is being dissolved—it resembles a stick of compressed salt to which water has been allowed access in one area The cancellous structure has disappeared the cortex appears to be dissolved except for small islands of cortex, linear in thickness There is no periosteal reaction, and there may be little change in the neighbouring bone unless the radiograph is taken after an interval of disuse of the limb when it will show osteoporosis (see Fig 121 B)

Although the radiographs may show this apparent destruction of the shaft healing may occur if the limb is subjected to radiation therapy and the appearance of radiographs taken after an interval may surprise one The whole outline and structure of

Hæmangioma of Bone. *Buey* and *Capp* illustrate the radiographic appearance of a hæmangioma of the neck of the scapula in a woman of 40 years of age which began to develop three years after an injury to the part The first radiograph shows an area of rarefaction as in a bone cyst, but one year later the area showed a coarse trabeculation radiating from a central point the appearance of the tumour being not unlike the top of a head of shaggy hair *Ewing*[3] has described a case in which an angioma developed in the head of the humerus two years after a severe trauma

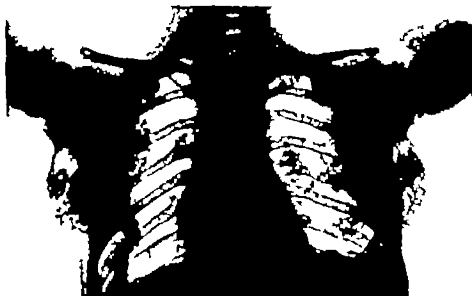


FIG. 120. Chondromatosis. Note that it invol es all borders of scapulæ and rib extremities.

Sarcoma of the humerus is not infrequent in adolescents Perhaps the most out standing feature of this type of tumour in the early stages is the presence of a definite solid, palpable tumour in association with little radiographic change in the bone The bone may show a little increase in density with obliteration of the detail of the cancellou structure and, later a thin line along a short section of one side of the shaft indicating periosteal new bone which may later show fine striations or spicules at right angles to the shaft of the bone—thickest at its central point and tapering to blend with the shaft at the extremities of the lesion of the periosteum The summit of this mound of new periosteal bone is usually absorbed and a crater is formed which may extend to the shaft, leaving what is sometimes described as a periosteal cuff on either extremity (see Fig 188). Coincident with this periosteal change the shaft shows progressive obliteration of its cancellous detail which is often most evident at the epiphyseal line, where it is in contrast with the normal epiphyseal bone which for a time appears to be protected from invasion by sarcomatous cells

In some cases the sarcomatous tissue attracts calcium, consequently the involved bone shows irregular areas of sclerosis with ill-defined borders. This osteoplastic reaction of the sarcomatous bone is often seen to follow X-radiation even in those cases in which osteolysis was the attractive feature

Ossifying Hæmatoma and Localised Periostitis produce a radiographic appearance which may be said to simulate sarcoma and indeed, it has been interpreted as such,

THE LOWER EXTREMITY

CHAPTER VII

BONES OF THE FOOT

OSSIFICATION

The only bones seen on radiographs of the foot at birth are the diaphyses of the phalanges and metatarsals and the nuclei for the os calcis, astragalus and sometimes two for the cuboid.

The nucleus for the os calcis is beginning to show indications of the typical shape of the bone It is formed by the fusion of two nuclei the first appearing about the fifth month of fœtal life and the second a month later

The nucleus for the astragalus usually appears during the seventh month. Late in the ninth month of intra uterine life or during the first month of extra uterine life the nucleus for the cuboid begins to ossify and this is followed during the sixth month by the third cuneiform. At the beginning of the second year the nuclei for the first cuneiform and for the epiphyses of the phalanges may be seen in the female, but in the male they may not appear until the third year A second or third nucleus for the first cuneiform is often seen dorsal and distal to the primary nucleus about the fourth year Towards the end of the second year in the female all the tarsal nuclei may be present together with the epiphyses of the metatarsals and phalanges. The heads of the metatarsals may all be developed from two ossific nuclei in the epiphyses. The epiphyses for the metatarsals and phalanges may be absent except for the proximal epiphysis of the terminal phalanx of the big toe, when all the nuclei for the carpal bones are well developed. In the male the nucleus for the middle cuneiform may not appear until the end of the fourth year The nucleus for the last tarsal bone, the scaphoid may be shown at the end of the second year in the female, but in the male it is not usually seen until the end of the third year In the third year three separate nuclei for the scaphoid may be shown. The epiphyses of the three middle toes may be the earliest to show ossification in some cases, whilst in others the epiphysis of the proximal phalanx of the great toe may be the first to appear The nuclei for the distal epiphyses of the tibia and fibula appear during the second year of life the tibial being first; in the female it may be seen at the end of the first year

ACCESSORY BONES OF THE FOOT

Besides the bones which are normally present in the foot additional ossicles are frequently found on radiographic examination.

A knowledge of these is important on account of the fact that their presence on the radiographs of feet which have been injured may lead to misinterpretation. They are generally but not invariably bilateral; consequently it is advisable to take a comparable radiograph of the opposite foot. The epiphysis at the base of the fifth metatarsal is perhaps the commonest ossicle to confuse the beginner because it often has a jagged surface the complement of which is seen on the diaphysis and it is often projected obliquely in such a manner that the epiphysis has the appearance of a fragment of bone which has been torn off Multiple nuclei for this epiphysis have been seen which give it a fragmented appearance A separate ossicle the extremity of the styloid process of the fifth metatarsal is the os vesalianum—the epiphysis is sometimes mistaken for this rare ossicle Attention is sometimes called to the os tibiale externum (*Pfitzner*)

the shaft may be regenerated. Similar regenerative changes have been observed after treatment of some cases with lead or *Coley's* fluid.

One should be aware of the fact that Lymphadenomatous Deposits and Syphilis of bone may produce somewhat similar radiographic appearances. Complete absorption of the inner half of the clavicle and a spontaneous fracture of the humerus has been seen in which the radiograph showed a large area of absorption of the osteoporotic shaft in a man of 35 in whom the shaft reformed after anti-syphilitic treatment the inner half of the clavicle did not re-ossify—its appearance simulating resection Nor should one neglect the consideration of a neurotrophic lesion in cases of spontaneous fracture followed by much bone destruction. The same radiographic appearances have been observed in such a case (see Fig 116).

Similar bony lesions to those described in the humerus have been observed in the scapula and clavicle

The multiple rounded areas of cancellous destruction, in places scooping out the compact cortex from within, may be the indication of Myelomatosis.



Fig. 123. Osteochondritis of the tuberosity of the scaphoid associated with an accessory scaphoid in a man of 34. Also similar changes in the sesamoid on the lateral aspect of the head of the first metatarsal.



Fig. 124. Radiograph showing "peroneal" ossicle with arthritic changes in the joint between it and the cuboid. Plantar calcaneal spur also shown.

the accessory scaphoid, because of a tender swelling on the medial side of the foot It receives some fibres of the tendon of tibialis posticus, and *Keith*[1] is of the opinion that because of its position and this attachment, it changes the pull of the tibialis posticus



Fig 122. Bilateral accessory scaphoid in a boy of 12. Note that the one on the left (A) has been displaced owing to a fall 2 years previously

while *Zadek* is of the opinion that it affords the chief attachment for the tibialis posticus. It may be displaced by trauma from its position as in Fig 122 A. It may develop from more than one nucleus

Osteochondritis of the opposing extremity of the scaphoid is occasionally met with as in Fig 123.

This ossicle was first described by *Baukin* in 1605

On the lateral radiograph of the astragalus a small projection is shown on its posterior aspect. This posterior process in some cases has no bony union to the astragalus and appears in the young person as a separate ossicle the os trigonum in a boy of 9 years it was seen as a separate round ossicle One year later it appeared to have fused with the astragalus. More rarely it is united to the os calcis and not to the astragalus *Thurstan Holland*[2] reported it to be present in 7–8 per cent. of his cases.

Bilateral synostosis between astragalus and os calcis astragalus and scaphoid has been seen.

Pfitzner found a small ossicle the secondary os calcis closely attached to the os calcis and in association with the joints between the os calcis scaphoid, cuboid and astragalus in 10 out of 840 dissections

The secondary cuboid is rarely seen. It is a small ossicle closely related to the plantar aspect of the distal extremity of the scaphoid and the medial aspect of the cuboid.

Dwight describes as the intercuneiform a small ossicle situated on the dorsum of the foot between the proximal extremities of the first and second cuneiform bones He also describes as the intermetatarsum a small ossicle free or united to the base of the

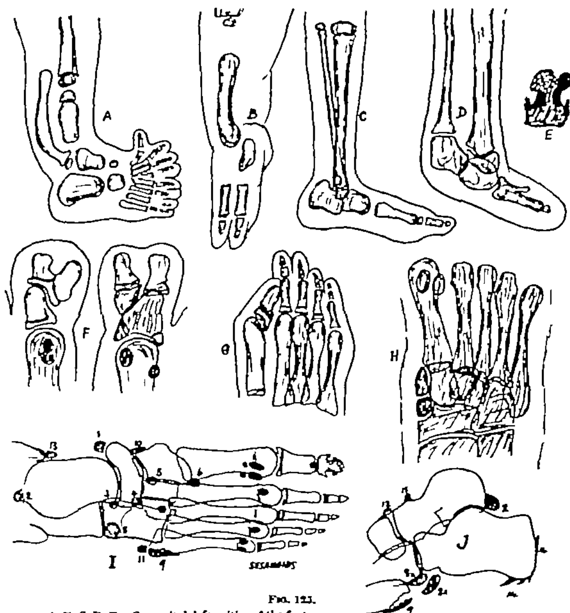


Fig. 123.

A, B, C, D F Congenital deformities of the foot.
E. Subungual exostosis.

G Myositis ossificans progressiva. Fusion of phalanges and deformity of the head of the first metatarsal.

H. Supernumerary digit. (Two cases showing these extra bones have occurred in the series.)

I and J Accessory bones and sesamoids (schematic).

1 Os tibiale externum (accessory scaphoid).
2. Os Trigonum.
3. Secondary os calcis.
4. Secondary cuboid.
5. Intercuneiform.
6. Intermetatarseum.
7 Uncinatum.
8 Peroneal sesamoid (articulating with inferior surface of cuboid).
8a. Peroneal sesamoid.
9 Epiphysis of fifth metatarsal
10 Paracuneiform
11 Vesalianum.
12. Astragalo-scaphoid ossicle
13. Os subtibiale (*Fairbank*).
14. Calcaneal spurs.
15 Astragaloid spur

first or second metatarsal bones. It may appear to be in two pieces. The os uncinatum is a small rare ossicle or process on the plantar aspect of the external cuneiform.

The sesamoid on the plantar aspect of the cuboid, sometimes appearing on the lateral radiograph to occupy the notch in the distal extremity of the os calcis, is a relatively frequent bilateral ossicle. It is in the tendon of the peroneus longus and is sometimes very closely related to the plantar surface of the cuboid, and arthritic changes may develop between the opposing surfaces I have met with this bilateral condition in a number of cases The radiograph suggests an ununited epiphysis of the cuboid (see Fig 124)

Cameron, also *Carlier* has described a small ossicle on the medial aspect of the first cuneiform and scaphoid which is called the paracuneiform. Fig 125 H is a tracing of a radiograph from one of two similar bilateral examples of extra ossicles in this position which have occurred in the author's series.

Kidner describes the accessory scaphoid as the prehallux, but I am of the opinion that the latter term would be more fitting for the ossicles shown in Fig 125, H, than for the accessory scaphoid, which has the radiographic appearance of an ununited epiphysis for the scaphoid. A small ossicle is frequently seen, more often in women, on the dorsum of the foot and closely applied to the joint between the scaphoid and the astragalus The radiographs of these ossicles suggest that they have perhaps become detached from the scaphoid by trauma associated with high heeled shoes. A separate ossicle—the os subtibiale—has been described by *Fairbank* at the extremity of the internal malleolus

The works of *Agati, Baarstrup Dwight, Ferguson Holland* and *Köhler* give additional facts relating to these accessory bones.

The position of the sesamoid bones which are from time to time seen in the foot are shown in Figs. 125 I and J

The two applied to the head of the first metatarsal are usually to be seen on radiographs. They may each be represented by more than one nucleus. Fractures of these sesamoids have been reported and it is conceivable that such may occur but frequently the multiple nuclei have led to the error Changes simulating osteochondritis as in Fig 128 are seen occasionally

Paget's Disease has been seen localised to one sesamoid in patients with typical changes in the opposite foot in the os calcis

Calcaneal Spurs. Sharp or irregular spurs of bone may be shown growing from the posterior part of the plantar surface of the os calcis and pointing distally and, more rarely from the supero-posterior aspect pointing proximally The lateral radiograph of the os calcis should be taken with the lateral aspect of the foot against the film—if the medial surface is used a spur on the plantar surface may be obscured. These spurs may cause the symptoms of "tender heel" It has been stated that these spurs occur only in association with gonorrhœal infection, but they are frequently seen in patients from whom no history or suggestion of such infection could be obtained. They have been seen to arise following trauma. Spurs due to trauma but not possessing the sharp character of the calcaneal spur are to be found on other tarsal bones *e.g.*, the astragalus, scaphoid and cuboid (see Fig 125 J).

Irregularity of the whole of the plantar surface of the os calcis is seen in some cases of syphilis and other chronic inflammatory conditions.

Congenital Deformities. The congenital deformities of the lower extremity are more serious to the child than the deformities of the hand

The severity of the deformity varies from complete absence of both legs, as in the case illustrated by *Foster* in which a radiograph of the pelvis shows no evidence of

ill-defined decalcification of the affected metatarsal it may be diagnosed as a sarcoma. In a number of instances this has occurred and has been followed by amputation of the limb. After 6–8 weeks organisation of the calcium will be seen and the fracture site will now begin to present the appearances of a plumber's wiped joint. In some cases



FIG. 127A. Radiograph of a foot (14/4/32) showing a fracture of the second metatarsal bone. Note the massive woolly callus. This appearance should not be mistaken for sarcoma.



FIG. 127B. Same foot as Fig. 127A (28/6/32). Note the more typical "mature" callus.

the new bone shows laminations, the so-called Onion like Periosteal Accretion, which may also confuse the novice. The whole metatarsal shaft may be thickened by deposition of subperiosteal new bone. Consolidation of the new bone proceeds and in 4–6 months the bone presents a thickened cortex and a more robust appearance than its neighbours. The lesion is sometimes referred to as Deutschlander's Disease (see Figs. 127 A and B).

Though generally occurring as an isolated lesion it may occur in association with simultaneous fractures in the third or fourth metatarsals, while in some cases one has seen that as the patient recovers from one fracture another occurs in a neighbouring metatarsal or in the opposite foot. In the unsuspected tabetic multiple fractures of the metatarsals have gone to the stage of deformity with callus before radiographs have been taken which revealed the cause (see General Discussion, page 629).

Mark Jansen has described this condition of march fracture and shows that this periosteal thickening is related to the insertion of the interossei, pointing out that it is absent from the first metatarsal, the lateral border of the fifth, the heads and basal portions of the metatarsals, from all of which no interosseous fibres arise, and that it is most marked on the medial borders of the third, fourth and fifth, from which both the plantar and dorsal interossei originate.

Kaplan has recorded a case (a woman of 85 years) of Multiple Spontaneous Fractures of Unknown Origin involving all the metatarsals of both feet, two metacarpals on one hand, and three proximal phalanges of both hands. No abnormality was seen in the spine or proximal limb bones. The most notable finding was that of 17 per cent. of eosinophil corpuscles in the blood.

Morton describing Metatarsus Atavicus (Metatarsalgia), a painful disorder of the anterior portion of the foot, states that it is associated with

(1) Unusual shortness of the first metatarsal bone.

(2) Tenderness elicited by deep pressure on the sole of the foot in the region of the second metatarso-cuneiform joint.

Isolated or multiple enchondromata and multiple exostoses may involve the phalanges of the foot. They show radiographic characters similar to those described in the hand.

In the condition of marble or chalky bones, the epiphyses of the proximal phalanges of the big toes may show fragmentation, and the extremities of the long bones and the *periphery of the tarsal bones show the first signs of the condition developing* the dense bone appears to be laid down in lines parallel to the epiphysis.

Isolated Islands of Compact Tissue, ovoid in shape, with their long axis in the line of the main bone trabeculæ, may be seen in one or more of the bones of the foot, but in the generalised type—**osteopoikilie**—multiple compact islands may be demonstrated as areas of increased radio-opacity in many or all of the bones of the foot. In the cancellous extremities of the metatarsals and phalanges the dense islands tend to be circular

Sub-ungual Exostoses. A cancellous exostosis growing from the extremity of the terminal phalanx of the great toe and pushing to the surface at the side of the nail is not an infrequent occurrence A radiograph will show the exostosis as a bud of cancellous bone growing from the side of the distal phalanx (see Fig 125 E).

A sub-ungual exostosis on the dorsal aspect of the great toe of a girl of 9 years recurred within 4 months of resection, *i.e.*, it must be completely removed.

Injuries. While it is not intended to describe the radiographic appearances of typical fractures of the bones of the foot, attention should be drawn to certain appearances which may lead to erroneous interpretation of the radiograph.

The epiphysis at the proximal extremity of the fifth metatarsal frequently has a very irregular surface opposed to a similar surface on the diaphysis it may show apparent fragmentation, and if the radiograph has been taken because of an injury to this area, such an appearance may lead to misinterpretation of the radiograph. If the appearance is not familiar to the observer a radiograph of the opposite foot taken in the same plane should be obtained and compared.

Multiple nuclei of the sesamoids of the big toe should not be mistaken for fracture

March Fracture. Fractures of the **Metatarsal Bones**, most commonly the second, may occur in any without any definite knowledge of injury Such fractures occur not only in soldiers who have been fatigued on the march but spontaneously in civilians of both sexes. In some cases there is history of more definite trauma and the painful sensation that a fracture has occurred. In a girl aged 19 years march fracture occurred within a month, in the left second metatarsal and within another week in the third right metatarsal, of resection of the heads of the first metatarsal.

They occur more frequently between the ages of 18–50 but some of the author's patients have been as young as 10 years. One woman aged 59 years had a sudden pain in the foot and when X-rayed 5 weeks after a march fracture through the middle third *of the first metatarsal with much callus was shown On examination a very tender spot* may be detected on the dorsum over the site of the fracture, later obvious swelling over the area will be seen.

Radiographs taken immediately after the onset of the symptoms may fail to reveal any sign of a fracture, or more commonly a very fine fissure may be seen with the aid of a magnifying glass across the distal third of the shaft. In both cases the cause for the symptoms may escape detection. Further radiographs after the interval of a week or fortnight may show a very definite fracture I have in one or two instances then re-examined the primary radiograph, but even with the knowledge that a fracture exists could not detect any sign of it. After an interval of 3–4 weeks a flocculent deposit of calcium in the subperiosteal hæmatoma may be seen around the fracture site If function *is permitted this tends to increase to such an extent that the fracture line may be obliter*ated, and as it is often associated with marked swelling of the dorsum of the foot and an

The author has radiographs showing the typical sequence of changes in isolated cuneiforms (see Fig 120) and sesamoids and epiphyses so it can be said that any of the primary or secondary centres of ossification may be the site of **Osteochondritis**

A condition of one or more of the metatarso-phalangeal joints which shows a radiographic sequence of changes in the extremities of the bones entering into the joint which simulate those seen in **Legg-Perthes Disease** has been described by *Panner* There is in some cases definite history of trauma a few months previously For some months there may be marked swelling of the soft tissues around the joint particularly on the dorsal surface, and movements at the joint are much restricted. At this stage considerable osteoporosis of the metatarsal head and base of the phalanx, in which are small circumscribed areas of cancellous destruction, are associated with splaying out of the base of the metatarsal while its thickened shaft appears to have the density of additional calcium. The decalcification of the subarticular bone gives a blurred appearance to the articular outline which may suggest an infective arthritis Eventually the lesions consolidate without leaving any permanent disability though radiographs may show pressure deformities of the bone which had been plastic during the acute phase.



Fig 120 Radiograph showing compression and increased density of the internal cuneiform (osteochondritis) associated with osteoporosis of the other bones of the foot (syphilitic).

Freiberg's Infraction or Köhler's Disease of the Second Metatarsal Head. This condition perhaps more closely resembles *Legg-Perthes* disease of the femoral capital epiphysis than osteochondritis in other sites, for in it changes are seen in the epiphysis, the joint space and the diaphysis.

All of the cases which the writer has seen were females, mostly under twenty years of age. *Freiberg's* first 6 patients and *Campbell's* 4 patients were also females, but of *Panner's* 13 cases 2 were males These figures indicated that the affection shows a preponderant incidence in the female sex, and in this respect it differs from *Legg-Perthes* disease

The age of the youngest patient seen by the writer was 13 years and of the eldest 38 years, but the bone changes and the clinical history suggest that in all the younger patients the bone changes began about the age of puberty Of *Panner's* 13 cases 10 were between the ages of 10 and 14 years. Similar changes have been reported in the third metatarsal and still more rarely in the fourth metatarsal. Though generally unilateral, in some cases it is bilateral. Several authorities, notably *Köhler* and *Panner* have recorded similar changes in adults but they explain that these were probably induced during the second decade of life and the changes have persisted into adult life There is no radiographic history published of the bones of any one of these patients to show the commencement and ultimate appearance of the condition, but that changes may begin in adult life is proved by the radiographs published by *Gaitskell*.

Ætiology The author has been fortunate in examining a number of patients soon

He also points out that the second metatarsal bone has a broader shaft and that its walls are thicker than normal

Radiographs illustrating bilateral features of this condition are shown in Fig 128. The condition appears to be more frequent in adult females.

Areas of rarefaction may appear in the tarsal bones following injury to the cancellous structure, as in the carpal scaphoid

Radiographs of the foot in which individual tarsal bones have been dislocated and then replaced show rarefaction of the other bones following the disuse, whereas the

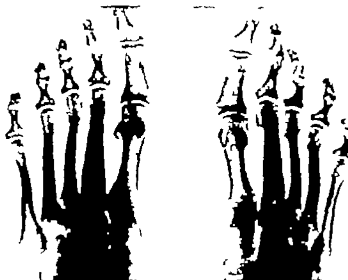


FIG. 128. Radiograph showing broadened shaft and thickened cortex of the second metatarsal which is associated with a short first metatarsal.

bone which has been replaced, frequently retains its density—it appears to be sclerosed because of the general rarefaction of the other bones. This appearance is generally due to the fact that it is avascular and it is not until the bone has been revascularised that it assumes the general density shown by the other tarsal bones

Osteochondritis. The characteristic radiographic appearances of osteochondritis have been recorded as being present in a number of different bones of the foot since the condition was first described in the tarsal scaphoid in 1908 by *Köhler*

Haglund in 1907 reported cases of osteochondritis of the os calcis.

In 1914 *Freiberg* and *Köhler* described a similar appearance in the head of the second metatarsal, and in 1924 *Renander* [1] published two cases showing changes in the medial sesamoid bone of the first metatarsal.

In 1920 *Silfverskiöld* [2] reported changes in the cuboid and os calcis, which he suggested were of the nature of traumatic malacia.

In 1928 *Diaz* recorded it in the astragalus.

In 1930 *Wagner* recorded it in the epiphysis of the first metatarsal.

Increased density of the epiphysis of the proximal phalanx with a suggestion of fragmentation may be found in girls and boys aged 10–12 in association with some swelling and early hallux valgus.

The radiographic appearances of the case of multiple manifestation of subchondral necrosis published by *Martin* and *Rœsler* are not quite typical.

or the medical officer to seek radiographic evidence until the secondary changes had led to aggravation and persistence of the signs

Unfortunately the majority of the patients recorded in the earlier literature had not been diagnosed until the lesions with their secondary changes were well established and the cause was deduced from the histological appearances With such cases the clinical radiological and histological evidence is confusing It has led to considerable controversy

Axhausen was confident that the changes were due to embolic obstruction of the vessels supplying the bone which became necrotic and subject to impression fracture some authorities regarded it as a localised avascular necrosis—others as localised inflammatory reaction *Freiberg* was satisfied that the condition was due to trauma and that it is usually associated with flat foot. *Kaplis Lang* and others hold that the histological evidence can be explained as the result of trauma. With the presence of secondary changes due to necrosis it must be almost impossible to assess the histological evidence and the divergence of opinion is not surprising It may be that in some cases embolic obstruction of vessels or localised inflammatory changes are the initial factors since these conditions have been associated with radiographic evidence of similar changes in the femoral head at any rate for a time. It might well be the explanation of the lesion in the adult case a lady of 59 years of age, published by *Gaitskell.*



FIG 181 Osteochondritis of the head of the second metatarsal bone. Right side. Note the irregularity of contour of the head of the bone, the thickened and sclerosed distal half of the shaft, including the neck the shortening of the metatarsal the widened and deepened joint space; and the expanded base of the opposing phalanx.

Diagnosis and Treatment. The appearances of the affected foot will depend upon the stage at which the condition has been suspected. In the earliest cases there may be the signs and symptoms of localised damage over the affected metatarsal and the patient will give the history of a definite injury sustained within the past week Often when first seen the foot is flat the patient giving the history of an injury to the foot some months before since which time the foot has been painful and swollen, but when rested the swelling over the dorsum of the foot diminished. Examination of the foot reveals a swelling over the heads of the metatarsals and the patient complains of pain when pressure is applied to the head of the second metatarsal. The radiographs will reveal the changes dependent upon the age of the lesion and the treatment it has received

The lesion differs from the Legg Perthes lesion in the femoral head in that it is frequently associated with detachment of loose fragments into the joint and their removal is called for as an essential feature in treatment. This does occur in some cases of Legg Perthes disease—it appears to be due to the application of stress and strain and separation of the fragments during the stage when subarticular fragments of incompletely revascularised necrosed bone are still present and but weakly attached to the adjacent living bone. Early recognition and sparing of the lesion from stresses and strains, even of the normal function, will not prevent the sequence of changes which follow avascular necrosis of bone but it will prevent deformity of the joint surfaces

after they had sustained a definite injury when the localised signs of damage to the part were present, but when the radiographs revealed no sign of change from the normal appearances of the bones or joint (see Fig 130). After an interval of 3 or 4 weeks further radiographs showed changes in the head of the affected metacarpal in the shape of some ill-defined osteoporosis and slight flattening of the articular surfaces of the head. In the course of the next few weeks compression of the metatarsal head became obvious—the compressed fragment appearing to have an added density while the adjacent extremity of the metatarsal showed localised osteoporosis (see Fig 130) The extent of the changes following this appears to depend on the amount of function to which the part is put. The explanation for the serial radiographic appearances appears to be that trauma caused damage to the head of the bone and the secondary reactions were mainly due to interference with the vascular supply of the sub-articular bone: this produced avascular necrosis of a fragment and this in turn induced hyperæmia



Fig. 130A. Freiberg infraction of head of the second metatarsal a few days after injury 18/3/46.

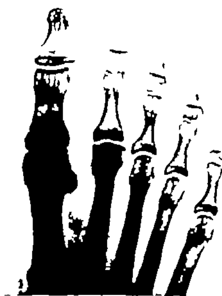


Fig. 130B. Freiberg infraction of head of the second metatarsal 26/6/46.

and decalcification of the adjacent living bone The extent of the reaction and the deformity of the bone being dependent for the most part on the amount of stress and strain of function to which the part was subjected—the less the function the less the deformity In those patients who have continued to use the limb after the secondary changes have been established we see flattening and irregularity of the metatarsal head with perhaps the separation of one or more small fragments into the joint cortical thickening of the neck and sometimes most of the shaft of the metatarsal, increase in the joint space (but in adult life when secondary osteoarthritis appears in the deformed joint this is reduced) and splaying out of the base of the softened proximal phalanx. It is probable that in many cases the trauma was sustained during excitement when it was unnoticed, as we have seen in cases of localised myositis ossificans, etc. the subsequent recognition of discomfort did not cause the patient to seek medical attention

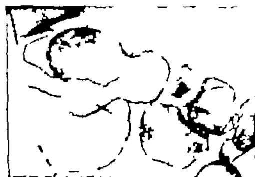
Dr. Iles has sent me prints illustrating the progress of a case which he was fortunate to radiograph before any bone changes had taken place and they show that on February 10th 1932, very slight bone changes were present on March 18th all the



Radiograph of the foot of M.T 10/2/32. It shows a slight relative density of the scaphoid but no deformity of outline or internal structure



Radiograph of the same foot, 18/3/32. It shows marked increase in the density of the scaphoid which still preserves its shape and internal structure whereas the other tarsal bones have lost much of their calcium and cancellous structure.



Radiograph of the same foot 7/9/32. It shows deformity of the scaphoid and absorption of the excess calcium. The other tarsal bones now show a greater calcium content and internal structure.



Radiograph of the same foot 11/11/32. It shows an increase in the density of the parts of the scaphoid which were first absorbed but some dense amorphous calcium deposits are still present. The other bones are now approaching the normal in density and structure

Fig 132. Köhler's osteochondritis of tarsal scaphoid.

bones of the foot are rarefied, except the scaphoid, which, normal in shape, stands out in strong contrast. The other mid tarsal bones show a clearly defined line periphery without any apparent internal structure or density By September 7th 1932 the scaphoid appears a much smaller irregular body having ill-defined areas of density irregularly disposed throughout the cancellous structure of the other mid tarsal bones has reappeared, but they are still rarefied and less in density than the condensed islands of the scaphoid. There is a reduction in the space between the astragalus and

and separation of fragments. Radiographic examination enables the surgeon to differentiate the condition from Deutschlander's disease of the second metatarsal (see pp. 144–5). A similar deformity to the head of the second metatarsal may be seen to follow a developmental defect as is shown in Fig 126B, a member of a family showing hereditary brachydactyly

Osteochondritis of Tarsal Bones. The typical appearances of Osteochondritis Dissecans (see p 107) have been seen in the head of the first metatarsal and on the articular surfaces of the astragalus and scaphoid.

Trauma of cancellous bone, as we have seen in the case of the carpal scaphoid, may result in destruction of a localised area of cancellous tissue and its ultimate absorption. This phenomenon is well illustrated by *Silfverskiöld*[2] in the radiographs of a girl 5 years of age who had sustained a severe injury to the foot 5 months before. The radiographs show a large area of cancellous absorption in the cuboid and the opposing end of the os calcis, giving the impression that this has been produced by a hæmorrhage in this area which has resulted in a pressure absorption owing to its confinement within the relatively rigid walls. It must be borne in mind that trauma may induce a focus of tuberculous caries which might at one stage present a similar appearance.

Trauma of cancellous bone in which the walls of the bone were involved has also led to disintegration of the cancellous structure, a phenomenon frequently seen in fractures of the vertebral bodies. In the case of osteochondritis there would appear to be some additional feature besides the trauma, otherwise one would not expect to find it so generally uncommon but relatively so frequent in females in whom it may be bilateral. The appearances could be produced by a lesion which resulted in obliteration of the vessels supplying the epiphysis followed by a reaction, due to the necrosis so caused, leading to increased vascularity subsequent softening of the bone its expansion due to proliferation of cells and exudation into the tissue spaces, together with pressure on the disorganised bone by the stresses and strains to which the part is normally subjected, completes the progress of events

In a previous paragraph it has been shown that the condition of **Metatarsus Atavicus** occurs in patients with short first metatarsals, and that the second metatarsal subjected to much more strain and stress than the normal, consequently becomes thicker and denser

Yet, in spite of this, one does not see the changes in the metatarsal heads in these cases that we should expect, if such changes were solely due to trauma.

What the additional feature is has not been established—it may be, in the cases showing these changes, that the nerve to the nutrient vessels was injured at the same time or that the condition arises from embolic infection of the bone with resultant disorganisation, subsequent pressure producing the deformity that is, the compression is secondary not primary

Holst and *Chandrikoff* have analysed the literature and illustrated many cases.

Osteochondritis of the Tarsal Scaphoid is seen in the radiographs of patients as young as 2 to 3 years of age—an age earlier than that given by many text books as the date of commencing ossification. Of the 120 cases reviewed by *Kohler* two-thirds of them occurred between the ages of 5 to 6 years, three-quarters of the patients being boys, many of whom showed the changes in both feet.

Attention is drawn to the foot by swelling of the dorsum, in the region of the scaphoid, painful to pressure The skin of the swollen area may show a reddish discoloration. There may be some wasting of the muscles of the leg and thigh. The whole bone is involved, and frequently when the first radiograph is taken the bone appears to be compressed and sometimes fragmented (see Fig 132).

women and two in men the characteristic lesion is an oblique splitting of the navicular and separation of the two fragments the inner fragment gradually gliding over the head of the astragalus to its medial side ; the outer fragment overrides the dorsal surface of the second and third cuneiforms. This breech between the two fragments reduces the distance between the proximal articular surfaces of the second and third cuneiforms on the one hand, and the head of the astragalus on the other and ultimately these cuneiform surfaces may even articulate with the head of the astragalus In the later stages severe osteo-arthritic changes develop in the abnormal mid tarsal joint It is a very crippling condition A lesion of this severity may be found on both sides More frequently however while one side presents the appearances described, the other shows less extensive changes such as osteochondritis dissecans or mere compression of the plastic outer third of the navicular All these patients showed evidence of pathological changes in the navicular of each foot

The ages of the first nine cases were as follows ; 22, 32 45 51 52 52 56 57 and 59 The cases seen since have all been over 40 In the two younger patients no secondary arthritic changes could be detected in the affected bones but in most of the others marked osteoarthritic changes were evident. The radiographs of one case when the patient was 52 years of age showed almost complete medial dislocation of the inner fragment of the scaphoid but no secondary arthritic changes were detectable Six years later severe arthritic changes were observed. This suggests that the displacement had occurred within a year or so of the first radiographic examination.

In some cases the first metatarsal was short the second metatarsal was hypertrophied, and the third, fourth and fifth metatarsals were atrophied. The other cases



FIG. 183. Lateral radiograph of foot, showing division of scaphoid in adult scaphoiditis.

did not demonstrate these features although in some atrophy of the metatarsals was suggested.

Müller and *Schmidt* have recorded bone changes in the adult scaphoid which gave similar appearances to those shown in Fig 183. But it was *considered that the* changes were probably the result of Köhler s disease in infancy as in the case cited on p 151

That the writer is now able to show 20 cases suggests that the condition is probably not very rare, but is not generally recognised.

In all cases trauma was the probable factor which initiated the changes

The onset of the lesion is indicated in different ways, thus —

the first cuneiform when compared with the healthy side On November 1st, 1933 the condensed areas have almost disappeared and the bone appears as a very irregular structure while the other mid tarsal bones are now approaching the normal in density (see Figs. 132) Radiographic examination of a number of cases over 3 or 4 years shows that gradually new bone is laid down around the disorganised nucleus which may retain its density until the whole bone has re-formed. After an average of about 18 months the scaphoid has assumed almost a normal appearance. The only evidence that the condition has existed may be slight compression at the site of articular facets In this case the very unusual appearance of recurrence developed, but when seen by the author in 1947 the bone appeared to be normal except for slight facetting The sequence of radiographic signs in these cases suggests that the calcium attracted to the scaphoid is abstracted from the neighbouring bones to which it is returned as the scaphoid regenerates

Jebens has illustrated the radiographic appearances over a period of 4 years of this condition which developed in a child of 2½ years of age

The radiographic appearances of osteochondritis can be produced by various infective organisms, *e g.*, pyogenic cocci or bacilli, *Tubercle Bacillus* etc. The causal organism if any of the common lesion has not been identified

Greenwood suggests that the condition is due to a blood-borne infection of the scaphoid setting up an osteomyelitis He uses radiographs of the foot of a boy aged 8½ years, showing the typical *Köhler's* scaphoid. The foot was swollen and painful, and on aspiration a culture of pneumococcus was recovered Later owing to marked inflammatory changes the foot was amputated and the tissue showed typical tuberculous granulation tissue

During this investigation similar appearances have been met with in the accessory scaphoid, the epiphysis at the base of the first phalanx of the big toe the first metatarsal and its lateral sesamoids, the first cuneiform and cuboid. It appears to require 3 to 4 years, or even longer before the bone is restored to its normal structure as shown in the radiograph though the primary symptoms may have ceased after a few months An interesting feature which is confusing to the clinician is that the radiograph may show no alteration in the structure or shape of the bone when the clinical symptoms are prominent, but that, as these diminish, the radiograph shows a definite increase in the destructive bone changes. The relative density of the involved bone in the early stage is the earliest radiographic appearance, and is as definite, though not so spectacular as the subsequent changes

Against the primary condition being due to trauma is the fact that the condition is not common after wrenching operations on the foot. In some cases of club foot this wrenching and manipulation is sufficient to cause definite injury to the astragalus, which can be recognised on a radiograph.

The following case is interesting in that respect.

During operation upon a right congenital club foot, in a child of 6 years of age, the tendo Achillis was divided and the foot wrenched, but as the deformity returned to some extent a subcutaneous fasciotomy combined with wrenching and manipulation was performed 3 years later and 2 years after this a similar further operation was performed.

Radiographs of the feet after the last operation showed no bone changes in the right foot but the typical appearances of osteochondritis of the left tarsal scaphoid, the foot which had not been subjected to any known trauma.

Osteochondritis of the Adult Tarsal Scaphoid. The author has described the condition of osteochondritis associated with listhesis of the adult tarsal scaphoid (see also p. 150).

In the fifteen cases investigated of osteochondritis of the tarsal scaphoid in adult

The recognition of this condition may be of very great importance as the following details will show —

A patient, a compensation case aged 31 years was sent to the writer with the request for a radiograph of the metatarsus. The patient had given a history of injury to his foot by falling from a ladder 2 months previously. The clinical examination suggested to the surgeon that a fracture of the metatarsus had been sustained. The radiographs showed the typical appearance the writer had described of osteochondritis of the adult scaphoid, at a stage which suggested to him that the condition had been present long before the alleged accident, and a report was given to this effect

Being a rare condition in the writer's experience copies of the radiographs were made and when these were compared with the radiographs of the cases referred to above it was found that they closely resembled the radiographs of the second case which had been taken 2 years previous to this accident

At a subsequent consultation the patient stated that he had never had any injury or disability to his foot prior to his recent accident (2 years previously at another clinic, where a radiograph had been taken by a radiographer he had given an account of a severe injury which incapacitated him for some months) and he had never had any cause to seek medical or surgical advice. A critical examination of the two sets of radiographs revealed that, not only the appearance of the diseased scaphoid, but even the cancellous structure of all the bones of the foot agreed. The patient had used the same surname but a different Christian name on each occasion.



FIG 133. Medial displacement of the scaphoid. Note accessory scaphoid; deformity of first and middle cuneiforms; hypertrophy of second metatarsal. Osteochondritis of the adult scaphoid.

TREATMENT From a study of these radiographs there would appear to be no question but that with the recognition of the early changes the foot should be put at rest until the bone has consolidated. *After the* extreme deformity such as that shown in Fig 133 has been produced, the surgeon may have to consider removal of the medial fragment, owing to the pain and discomfort caused by the abnormally placed bone. Other illustrations are to be found in the author's paper [22]

In a later chapter reference is made to the condition known as apophysitis of the os calcis. This condition is associated with signs of localised inflammation, and radiographs sometimes show a fragmented appearance of the apophysis as in Fig 134 Some of the fragments are denser and more irregular than others The clinical history and radiographic appearances are somewhat similar to osteochondritis in other sites, the abnormal radiographic appearances persisting longer than the clinical signs As the ossification of the apophysis begins in two or more nuclei the appearance of the normal may be mistaken for that of osteochondritis.

Pain in the big toe joint with limitation of movement in the young person may be associated with increased density of the basal epiphysis (see Fig 136). In some cases this is the forerunner of chronic arthritis in the joint.

The dense epiphysis may appear to be split into two parts by a fissure in the mid line This may be seen in *girls about the age of 12 years* who complain of pain. Even at this age there may be associated *pointing* of the lateral articular margin of the head of the first metatarsal.

In the youngest patient a woman of 22 years, the condition had developed in both feet after four years of nursing duty She could not remember any definite accident but it is conceivable that she strained the feet in the course of her duties.

In a second patient a man of 31 years, the lesion had developed as a unilateral affection after a severe injury to the foot which incapacitated him for some months.

In a third patient, a woman of 52 years, the first symptoms had appeared 1 year earlier

In a fourth case, the patient had complained of pain in the foot for several years, and a hard swelling (the displaced scaphoid) had "developed" on the inner side of the foot during the last 2 years.

A fifth patient a man of 54 years, had complained of pain in the arch of the left foot for 5 years.

The youngest patient noticed in the first instance that the feet ached, and were swollen at the end of the day's duties. These signs diminished with rest, but they gradually assumed such a significance that she sought surgical advice. There was no increased temperature, but as the swelling persisted and the pain recurred at intervals, she was examined again. The patient now stated that she had felt a "crackly sensation" in the middle of the foot when she was walking. The foot was radiographed 10 months after the onset of the symptoms, and as a result of the unusual appearances shown, she was submitted for further advice.

The feet when examined were found to be swollen over the scaphoid region, and there was some reddening of the skin and tenderness on firm pressure over the bone. The signs were more marked on the right side. The antero-posterior radiograph shows an oblique fissure through the right scaphoid, the lateral fragment being "squeezed" in a dorsal and lateral direction from the normal position, the medial fragment consisting of about two-thirds of the bone being displaced, in a plantar and medial direction. The left scaphoid appears to be merely compressed in its lateral half. The lateral radiograph of the left foot shows an increased density of the proximal surface of the scaphoid from which a small fragment has been "separated." The lateral radiograph of the right foot shows an oblique fissure running through the scaphoid from the dorsum backwards and downwards and it shows the dorsal displacement of the lateral fragment and the plantar displacement of the medial fragment



FIG. 134 Bilateral medial displacement of the scaphoid with chronic arthritic changes i the mid-tarsal joint Osteochondritis of the adult scaphoid

A further stage of the compression is illustrated in Fig 134 where it will be seen that the medial fragment have now been squeezed so far medially that they produce a bony projection on this aspect of the foot and the head of the astragalus is now on a plane with the posterior surface of the cuneiforms. Finally in Fig 135, it will be seen that the medial fragment of the scaphoid has been completely displaced on to the medial surface

phalanx appears to be eroded, in others some or all of the phalanges and most afts of the metatarsals become absorbed the distal elements of the bones of being represented by the bases of the metatarsals with short sharply tapering les (see Fig 187). In other cases the typical appearances of a Charcot's joint may



Fig 189 Bilateral multiple Charcot joint in ankle and foot. ? Syphilitic

involving any one or more of the joints of the foot (see Figs 188 and 189) The rso-phalangeal joints may be the only ones to show definite changes Similar occur in yaws

ile the discovery of such lesions suggests to the clinician the more common ons of Tabes Dorsalis, Syringomyelia, Leprosy Psoriasis, etc., it should, however e in mind that identical appearances have been found in association with con- or pathological conditions of the lower spine such as Spina Bifida Occulta and ratoma, for in some of these conditions operative measures may lead to improve r cure

adiographs illustrating these lesions have been published in the articles by *Kienböck*[2] bifida occulta lumbosacralis), *Ström* (arthropatia psoriatica) *Borak* (Raynaud), r[2] (spontaneous fractures of os calcis in a tabetic patient), *Guillain, Mathieu* and *llet* (lumbo-sacral syringomyelia).

ypoplasia of all the bones of the lower extremity on one side has been seen by the in a case showing Multiple Hemivertebræ associated with paralysis of the ity (see Fig 17).

arked osteoporosis of the cancellous extremities of the metatarsals and phalanges the tarsal bones which may be associated with relative sclerosis of the shafts of tatarsals has been seen to follow trauma and arthritis in the mid-tarsal and ankle This may also be due to trophic disturbances. Osteoporosis of the Phalanges etatarsus may be a striking feature in the gangrene of diabetes (see Fig 141A.)

W *Spinzig* has given a good account of the clinical and radiographic findings hum which he describes as a disease peculiar to negroes characterised by a narrow strip of hardened skin which gradually embraces the entire circumference

Trophic Changes. Destructive erosion of the phalanges and metatarsals occurs as the result of trophic disturbance in **Tabes Dorsalis, Syringomyelia, Psoriasis Raynaud's**



FIG 136. Radiograph showing increased density of the basal epiphysis of the proximal phalanx of the big toe In some cases the dense epiphysis shows fragmentation.

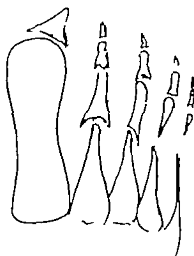


FIG. 137 Radiograph showing atrophy of the metatarsal and phalanges with destruction of the joints (case of psoriasis).

Disease, Leprosy Syphilis Yaws, Congenital and other **Pathological Conditions** of the **Spinal Cord.**



FIG. 138 Radiograph showing erosion of the heads of the metatarsal in a case of syringomyelia.

The radiographic appearance varies **Multiple Spontaneous Fractures** of the **Phalanges Metatarsals or Tarsal Bones** may occur In some cases only the extremity of the

and prepatella bursa) only in a small percentage of early cases but they are present in about 50 per cent of the well-established cases they consist of sodium urate. The serum uric acid may be increased to 6 per cent (normal blood contains 2 per cent. of uric acid by the uricase method).

An acute attack may begin very suddenly at night or in the early hours of the morning It may be brought on by an accident, surgery rich feeding or indiscretions in diet there may be a familial history It may be associated with renal colic or polycythemia. It has been recorded in adolescence but is more commonly met with over the age of 40 years. It shows a favourable response to colchicine The radiographs of the feet in gout may show no bone changes or only a punched-out area of cancellous destruction in the base of the proximal phalanx or the head of the metatarsal of the great toe—the appearance is not unlike that of a Brodie's abscess as seen in the larger bones



Fig. 141 Radiograph in a case of gout showing destruction of metatarso-phalangeal joints of great and little toes in association with large "gouty" deposits in the surrounding tissues.



Fig. 141A. Radiograph of foot showing decalcification of the bones with destruction of some of the joints in a case of diabetes.

and it has been diagnosed as such. Disintegration of the bones may be associated with large "gouty" deposits around the joints (see Fig 141). In chronic cases multiple rounded excavations (which may fuse and so bring about complete destruction of the extremities of the bones) are shown in the same sites also peripheral spurs from the extremities and tuberosities of the phalanges and metatarsals producing great deformity of the bony outline (see Fig 141). There is no systemic decalcification or bony ankylosis as in rheumatoid arthritis: these appearances are well illustrated by *Assmann Dillenseger* and *Audoux* and *Schin*...

Trophic Changes. Destructive erosion of the phalanges and metatarsals occurs as the result of trophic disturbance in **Tabes Dorsalis Syringomyelia Psoriasis, Raynaud's**



Fig 186. Radiograph showing increased density of the basal epiphysis of the proximal phalanx of the big toe. In some cases the dense epiphysis shows fragmentation.



Fig 187 Radiograph showing atrophy of the metatarsals and phalanges with destruction of the joints (case of psoriasis).

Disease Leprosy Syphilis, Yaws, Congenital and other **Pathological Conditions of the Spinal Cord.**



Fig 188 Radiograph showing erosion of the heads of the metatarsals i case of syringomyelia.

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FIG. 141. Radiograph in a case of gout showing destruction of metatarso-phalangeal joints of great and little toes in association with large "gouty" *deposits in the surrounding tissues.*



FIG. 141A. Radiograph of foot showing decalcification of the bones with destruction of some of the joints in a case of diabetes.

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of the little toe on a level of the digito-plantar fold. This constriction becomes deeper and produces a strangulation of all the tissues under the fibrous ring together with an absorption of the bone After a varifying period of time the distal end of the toe becomes enlarged and bulbous and is attached by a mere pedicle The final result is a spontaneous amputation of the distal end of the toe due to gangrene or accidental injury It occurs in South America West Indies West Coast of Africa Egypt and India.

Radiographs show erosion at the neck of the proximal phalanx of the little toe and gradual separation. The cause is unknown. Sometimes the lesion is preceded by a corn. It is more frequent in males between 30–35 years. It involves one or both little toes simultaneously or successively The duration is from 0 months to 5 years. After amputation the stump heals readily

It is distinct from Leprosy which occurs in any race, may involve all toes and fingers without the characteristic constriction, and is associated with vesicles bullæ and ulceration. Its lesions begin in the bulbous tip of the extremity and progressively spread to the metacarpals or tarsals: they yield the leprosy bacilli.

Raynaud's Disease is distinguished by its more common involvement of the upper extremity in females of all races and by absorption of the cancellous tuft at the extremity of the terminal phalanges and pain on exposure to cold due to circulatory changes

Trench Feet. During the 1914–18 war men whose feet had been subject to cold and wet for long periods in the trenches showed destructive erosion of the phalanges and the



FIG. 140. Trench feet. Note dislocation at the metatarso-phalangeal joints with erosion of the articular surfaces.

metatarsals. Radiographs of these trench feet showed appearances very similar to those associated with neurotrophic and vascular lesions (see Fig 140)

Gout. The big toe joint is involved in about 90 per cent. of cases of gout The term "podagra" which was applied to the acute inflammation of the first metatarso-phalangeal joint is now regarded as synonymous with gout. The periphery of the joint appears to be the more commonly affected. Multiple joints may be affected—the symptoms in one may be subsiding while in another they are increasing Achilles tendinitis may be present Tophi are found in the ears (sometimes in the olecranon

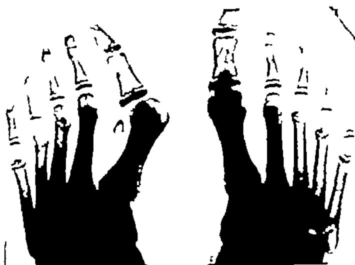


Fig. 144 Radiograph showing hallux valgus in the left foot of a young person



Fig. 145 Hallux valgus. Dislocation of the first and second toes at the metatarso-phalangeal joints. Cystic degeneration of the subarticular bone of the head of the first metatarsal and the base of the first phalanx.

Very marked osteoporosis of the bones of the foot with destruction of one or more metatarso-phalangeal joints may occur in diabetes (see Fig 141A).

Reaction to Strain. Pain in the mid tarsal area may be the result of prolonged strain, i.e. the weight of a heavy body Radiographs in such cases may show a zone of sclerosed subarticular bone at the principal surface bearing the strain. Thus the posterior subarticular surface of the scaphoid may show such a zone ⅛ inch in thickness without any changes in other bones Reaction of this type is seen in other subarticular surfaces which have been subjected to prolonged strain in the borders of false joints produced by the abnormal approximation of bony surfaces. Osteitis condensans ilii appears to be of this nature (see p 344)

Osteoarthritis. Osteoarthritis of the first metatarso-phalangeal joint is one of the commonest lesions of the foot All stages and appearances of the condition are met with. The first indication may be the progressive development of a beak on the lateral margin of the articular surface of the head of the metatarsal (see Figs. 142 and 143) This is succeeded by diminution of the joint space, sclerosis and flattening of the articular sur



FIG. 142. Radiograph showing beaking of lateral aspect of head of first metatarsal associated with depression in opposing surface of base of proximal phalanx. *Early changes of chronic arthritis* in a girl aged 18 years.



FIG. 143. Radiograph showing the late stage of chronic arthritis of the great toe joint in a man aged 56 years.

faces and further development of osteophytes at all the articular margins. These impinge upon one another and are pushed laterally and medially Articular surface erosion and cyst like areas of cancellous destruction appear in the sub-articular bone These tend to disappear with the rest as after McMurray's resection of the proximal half of the opposing phalanx. In the early stages the appearance *of Osteochondritis Dissecans may be seen* in the superior surface of the metatarsal head

Septic Infection of the Joint may produce *clinical signs which may be mistaken for* gout

Chronic arthritis of the mid-tarsal or ankle joint sometimes results in osteoporosis of the cancellous extremities of the metatarsals and the tarsal bones, while the shafts of

A triangular area of osteoporosis with little detail of cancellous trabeculation within it is sometimes seen in the os calcis. It varies in its size definition and contrast (see



Fig 147 Tuberculous caries of the astragalus and os calcis. Note the crushing of the astragalus and the scattered deposits of calcium indicating an old lesion.



Fig. 148. Triangular area of osteoporosis in the os calcis.

Fig 148). It does not represent any active lesion and is to be compared with the areas of cancellous destruction seen in the head of the humerus It must be distinguished

the metatarsals appear to have become unusually dense In the early stages of arthritis due to tuberculosis etc these features may be recognisable for a time

Rheumatoid Arthritis. In this condition also the radiograph may show all the stages of the disease including marked atrophy of the bones, when they are slender and radio-translucent reduction in the joint space erosion of the articular surfaces which often first occurs on the lateral aspects and not as in osteoarthritis on the opposing weight bearing surfaces destruction of the joint surfaces multiple small rounded areas of cancellous destruction dislocation with or without bony ankylosis Similar changes are also seen in the juvenile form.

Hallux Valgus. In the young person this is not associated with any irregularity of the joint surfaces (see Fig 144) but in the adult marked irregularity as in osteoarthritis may be present (see Fig 145)

Hallux Rigidus may commence as in Fig 130 but it later shows osteoarthritic changes

CHRONIC INFLAMMATORY CHANGES

Tuberculosis Tuberculous dactylitis is not met with as frequently in the foot as in the hand. Multiple small joint lesions may be present (see Fig 146). Tuberculous caries of the tarsal bones may commence in any bone and may destroy it with or without destructive caries of adjoining bones The affected bone shows in the early stage a small area of cancellous destruction associated with rarefaction of the other bones of the foot. Later the margins of the affected bone become eroded and the bone loses its

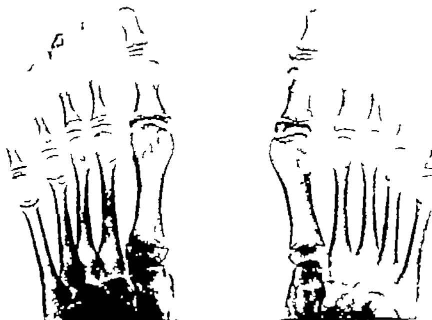


Fig. 146. Tuberculous arthritis of first metatarso-phalangeal joints (bilateral) and left third phalanges.

normal contour while its structure shows absence of cancellous trabeculation. As the lesion heals small deposits of calcium may be seen in the cancellous tissue (see Fig 147). In the acute phase, the bones which are not diseased usually show marked osteoporosis but sharply defined linear margins within which is a zone of decalcification about $\frac{1}{16}$ inch thick.

may show irregularity of contour with areas of sclerosis and erosion (see Figs 92A and 94) The good response to anti syphilitic medicaments is of diagnostic significance

Irregular erosion and sclerosis of the plantar surface of the os calcis (bilateral) has been seen in cases of syphilis.

Sartory and *Meyer* have recorded a case (a boy of 12 years of age) with radiographs showing areas of rarefaction in the right and left os calcis and the internal malleolus suggesting a fibro-cystic osteitis. Examination revealed that the lesions were due to **Hypermycetes.**

Madura Foot is a slowly progressive chronic inflammatory condition due to infection by the **Actinomyces Maduræ** probably obtained from the soil Lesions may occur in other sites but the bare foot offers greater possibilities of infection

The foot is swollen and œdematous and after a time exhibits multiple sinuses Radiographs show marked osteoporosis associated with multiple rounded areas of

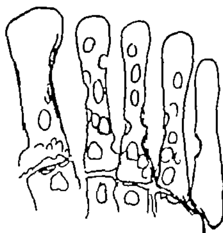


FIG. 151. Line drawing of radiograph of Madura Foot showing multiple rounded areas of destruction in generally decalcified metatarsals.

cancellous destruction which represent foci of infection. These lesions, which may be found in any bones of the foot, may become confluent they are perhaps most prominent when they involve the metatarsals as in Fig 151

A good account of this disease in a man of 60 years is given by *A Jaubert de Beaujeu.*

R A Carter has published an account of an **Infectious Granuloma of the Bones** due to *Actinomyces* His illustrations show the appearance of an organised subperiosteal hæmatoma

In a number of cases which were radiographed because of a "tender" heel the radiographs revealed an isolated **Osteitis Deformans** of the os calcis In one case (*Fig 152*) a spur was also present on the plantar surface of the os calcis Inflamed bursæ at the origin of the tendo-Achillis may be associated with an area of erosion of the posterior surface of the os calcis just above the attachment of the tendon The tendon may be ruptured with avulsion of fragment of os calcis. Separate ossicles may develop in the region of the tendon (see Fig 100) Paget's disease of the astragalus has also been seen by the author as an isolated or bilateral lesion.

Radiography of a tender heel in children from 6 to 12 years of age may show an irregularity of outline woolliness or fragmentation of the epiphysis of the os calcis This is frequently associated with an inflamed bursa but in many cases little bone change can be seen on the radiograph

from the simple cyst which is sometimes found in this neighbourhood (see Fig. 149). The specimen illustrated contained cholesterin. Mr Brockman's case



Fig. 149. Cyst in os calcis (contained cholesterin).

Syphilis. The appearance of syphilitic bone lesions in children may lead to the diagnosis of tuberculosis. As a general rule it may be said that the other bones do not show the atrophy in syphilis that is seen in tuberculosis, and in the latter there appears to be a greater tendency to spread to neighbouring bones, whereas in syphilis a tarsal bone may be completely destroyed without any apparent involvement of its neighbour and often multiple lesions are to be discovered by radiographing the skeleton. In the baby a clue as to the nature of the infection may sometimes be obtained by radiographing



Fig. 150. Radiograph of the foot of a boy aged 1 year showing irregularity of the contour and structure of the cuboid. Note the lines of condensation at the lower extremities of the tibia and fibula. A further radiograph of this patient three years after showed complete disappearance of the cuboid, normal appearance of all the other bones of the foot, but definite lines at the lower ends of the tibia. Syphilis.

the extremities of the diaphyses of the larger long bones. In syphilis irregular lines of condensed bone on a thin layer of decalcified bone may be seen. The affected bone

portion of the surface articulating with the astragalus is shorn off and is sometimes driven downward. The medial fragment containing the sustentaculum tali usually remains in place, while the middle portion of the bone and the lateral fragment are displaced laterally and appear as a hard bony mass below the lateral malleolus. He points out that normally there exists between the upper contour of the tuberosity of the os calcis and the line uniting the highest point of the anterior process with the highest



Fig. 151. Bilateral apophysitis of the os calcis.

point of the posterior articular surface, an angle of 30 to 35 degrees, the "tuber joint" angle. In fracture of the os calcis this angle becomes smaller, straight or even reversed and this displacement is maintained by muscle pull.

Bilateral comminution of the posterior third of the os calcis has been seen by the author in tabes.

Tumours of the Bones of the Foot. Multiple exostoses and enchondromata are amongst the most frequent tumours of the bones of the foot. Simple cysts occur (see Fig. 140).

Examples of most types of bone tumours have been seen and they present radiographic appearances similar to bone tumours in the hands. *J. R. Moore* reviewed 1,740 tumours which had been examined at the Johns Hopkins Hospital and found that 33 involved the os calcis (2 per cent.). They consisted of Exostosis (23), Chondroma, Giant celled Tumour, Chondrosarcoma and Ewing's Tumour.

Davidson and *Kurtz* reported a giant-celled tumour of the astragalus which was brought to notice by an injury. *Miltner* and *Wan* reported a giant-celled tumour of the os calcis in a male Chinese of 20 who had had pain in the heel for 2 years, with no history of trauma.

Radiography of a tender heel in adolescence may show an irregularity or fragmentation of the epiphysis of the *os calcis*, and this may be associated with an inflamed bursa (see Fig 154). Such irregularity in ossification may be *present without symptoms*



Fig 152. Osteitis deformans of the os calcis. Plantar spur also present

Achilles tendinitis is seen in some cases of gout with or without bone changes in big toe

Schwabauer and *Stern* have illustrated cases of calcaneal spurs, osteitis apophysitis, achillobursitis and periostitis.



Fig 153. A. Avulsion of insertion of tendo-achillis from os calcis with Paget disease 11/3/43.
B. 26/7 43. Fusion of fragments and changes in internal structure
C. 18 1 47 *Consolidation. Note coarse cancellous pattern.*

Wakeley [4] has illustrated a bilateral apophysitis of the os calcis in a boy 9 years of age. Several observers have described the radiographic appearance of endemic enlargement of the os calcis in young adult West Africans The outer posterior surface of the bone appears to be thickened and sclerosed.

Böhler has an interesting series of radiographs showing fractures of the os calcis He points out that the lateral wall is broken off while on the medial side the posterior

Fractures. The tibia is one of the bones in which incomplete fractures occur. The usual site is the upper third; less frequently the lower third of the tibia or the fibula shows evidence of these March Fractures (see p. 144).

Fractures of the lower ends of the tibia and fibula are amongst the commonest fractures seen. Radiographs usually give a clear indication of the bone damage, but it is most essential that radiographs be taken in the two planes, *i.e.*, antero-posterior and lateral, as it is a very common finding that in one plane no evidence of fracture can be seen, but on the other plane an obvious fracture is shown. It is also important that the radiograph includes the proximal joint, for this permits of judgment of rotation of fragments and the condition of the superior tibio-fibular joint.

Irregularities in the ossification of the tuberosity of the tibia occur and a separate ossicle may exist which may be mistaken for fracture.

Separate ossicles are also seen from time to time at the lower ends of the tibia and fibula, possibly the result of old injury. A linear shadow is sometimes seen on the lateral surface of the external malleolus on radiographs taken after injury to the part. This shadow suggests the separation of a thin scale of bone, but it is probably of the nature of ossification in the damaged ligament. A similar appearance is seen above or on the side of the inner condyle of the femur — the so-called Pelligrini-Stieda lesion, see p. 190.



FIG. 185. Radiographs (26/7/21) showing an ununited fracture of the fibula and three cyst-like structures in the middle third of the shaft of the tibia. The right figure shows non-union of the fragments (15/9/21).

Pseudarthrosis. The junction of the middle and lower thirds of the tibia and fibula is a site at which fractures of these bones in children frequently fail to unite. Such ununited fractures may even be present at birth, and the frequency with which this site

CHAPTER VIII

TIBIA AND FIBULA

OSSIFICATION

THE nucleus for the shaft of the tibia begins to ossify about the seventh week of fœtal life and that for the fibula about one week later The nucleus for the epiphysis of the upper end of the tibia appears within the ninth month of fœtal life or the first few weeks after birth, for the lower epiphyses of the tibia and fibula during the second year and for the upper end of the fibula during the third to fourth year The lower tibial epiphysis unites first at 15 to 18 years, the upper end of the tibia and lower end of the fibula at 16 to 20 years and the upper end of the fibula at 20 to 25 years

Osteochondrosis Deformans Tibiæ (Tibia vara). *The legs of the newly born infant* show a slight bowing which is gradually corrected in the normal infant but in those with abnormal bowing or plasticity of the bone compression may occur By careful strapping and corrective measures the shape will be restored, but if the bowing is permitted to persist permanent deformity such as described by *W P Blount* will result. *C Glenn Barber* describes two types infantile and adolescent. The infantile type is *seen in children who are of normal development but overweight It is usually bilateral* and when mild gradually disappears. If unilateral it may cause a limp or if bilateral a waddle Radiographs show splaying out of the medial femoral condyles in a beak like fashion—the lower epiphyseal lines are directed inwards. The femora are directed outwards—the tibiæ inwards. There is an indication of delay in ossification of the tibial epiphysis No evidence of rickets or syphilis

The adolescent type appears to develop between 6 to 12 years of age—it may continue from the infantile type—usually unilateral resulting in similar deformity of the joint surfaces and direction of the shafts. Considerable reduction of the deformity can be brought about by the use of wedged casts from counter pressure and manipulation if kept up during the plastic stage Recurrence may occur even after osteotomy if the correction is not maintained until consolidation has occurred.

Tibia Recurvatum (Back knee) This is a backward bowing of the upper half of the tibia causing the plane of the articular surface to slope downwards and forwards—the opposite to the normal On the antero-posterior radiograph the patella is low in position and the condyles appear to lie in close contact—the lateral radiograph shows that this is not so.

The condition is uncommon and has been described as a bilateral and as a unilateral deformity Clinically when viewed from the lateral aspect the leg appears to be subluxated backwards at the knee joint. The ætiology is not definitely known Trauma, inflammatory changes plasticity of bone from any cause and coxitis have been cited An illustrated account has been published by *K. Lübschitz.*

Congenital Abnormalities. Congenital deformities of the tibia and fibula range from complete absence of the whole or part of one bone to slight irregularities of the tibial tuberosity The commonest abnormality is congenital absence of the fibula Representative examples of some of the cases met with are shown in Fig 125 A B and C. Congenital synostosis of the upper ends of the bones occurs *Schwartz*, also *Evans* and *Smith*, have illustrated cases showing congenital absence of the tibia.

One leg and its bones may be much shorter than its fellow though the radiograph may show no reason for it.

search for them is essential *Stevenson* has recorded such a finding in a man of 22 years of age who had the history of having twisted his ankle 4 years previously The loose body was ovoid in shape and measured 1 by ½ inch.

DEVELOPMENTAL BONE ABNORMALITIES

In **Achondroplasia** the radiographs do not show any definite departure from the normal rate of ossification, but the diaphyses are shorter and the surface irregularities for muscle attachment are pronounced In the typical achondroplasiac dwarf the fibula is longer than the tibia but atypical cases occur in which the fibula is much shorter than the tibia, as in the case illustrated by the author [21]

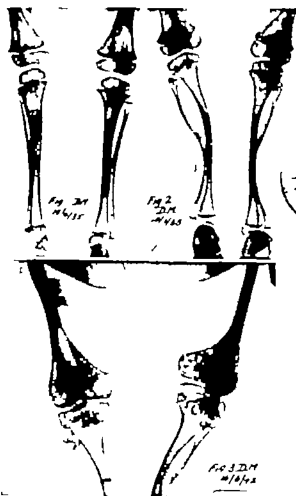


Fig. 157 Osteogenesis Imperfecta.

Osteogenesis Imperfecta. The bones of the legs in the early months of life may appear to be slender but the osseous borders of the metaphyses may be quite regular (see Fig 157 1). Gradually with time the shafts are atrophied and bent by muscular action and weight while the metaphyseal borders become irregular suggesting cartilaginous proliferation (see Fig 157.2)

is so involved suggests some congenital abnormality. A false joint may be formed, the conical upper extremity of the lower fragments articulating with concave expansions of the upper fragments. In some cases the concavity is on the lower fragment (see p. 120). The lower fragment of the tibia often shows multiple transverse lines throughout most of its length. In some cases fibrous union takes place between the fragments. This permits anterior angulation of the fragments and the deformity persists through life (see Fig. 150). See Fick's theory (Fig. 107, p. 120).



FIG. 154. Pseudarthrosis of the tibia and fibula in adult—common site

Operative measures to promote union of these fractures of childhood are frequently unsuccessful. In one case in my series when the child was born, a lump was noticed at this site. No radiograph was made until the child was 9 years of age. It showed an ununited fracture of the fibula and three cyst-like structures were present in the middle third of the tibia (see Fig. 155).

An osteotomy was performed to correct the curvature of the tibia which had developed. This resulted in an ununited fracture of the tibia which failed to fuse even with the implantation of a bone graft, the graft being absorbed. In some cases localised or generalised defective ossification or cyst-like formation has been seen in the infant tibia within its first year. Fracture through this has resulted in pseudarthrosis and grafts have failed. In other cases the localised lesion has been interpreted erroneously as a sarcoma. In *Von Recklinghausen's* neurofibromatous pseudarthrosis may occur as a complication. Some authorities have ascribed the above-mentioned cyst-like changes in the tibia as evidence of neurofibromatosis, though no clinical evidence in support is present. The tissue removed from the site may be regarded as having the histological characters of a neurofibroma.

Henderson investigated a number of these cases. He found that of seven cases which were discovered in early childhood, operative measures were unsuccessful in producing union in every one. Whereas in a group of six children in which the fracture was sustained in middle or later childhood, operation resulted in good union in five cases—the one which failed to unite was operated on under puberty.

An interesting experiment on the development of Pseudarthrosis was made by *Müller*. He bridged the ankle joints of rabbits with a bone graft which on fusion with the parent bone fixed the joint, but in each case a pseudarthrosis developed in the graft in the line of the ankle joint without any symptoms of fracture.

Grafts bridging the intervertebral discs or passing from the great trochanter to the ilium have been seen by the author to develop a pseudarthrosis in the middle of the bridge.

Loose Bodies in Ankle Joint. The discovery of loose bodies in the ankle joint is an infrequent occurrence, but their frequency is greater than this would suggest. Careful

and increased density of the shaft of the bone with a relatively small area of central rarefaction (see Fig 171) They may completely disappear on efficient medication.

A less common radiographic appearance of syphilis is that associated with osteoporosis In this condition the tibia and fibula are markedly bent the upper and lower extremities preserve their normal width, but they taper rapidly into a slender shaft The extremities are rarefied and the cancellous trabeculation appears to be broken down, leaving large areas devoid of structure—the shaft on the other hand often shows a relative sclerosis in its middle third, an appearance which simulates osteogenesis imperfecta tarda (see General Notes pp. 620–6).

The type associated with irregular sclerosis is shown in Figs 170 and 93.

Tuberculosis. Tuberculosis of the tibial shaft in infants may result in complete disintegration of the bone within an involucrum two to three times the thickness of the



FIG. 172. Radiograph showing one type (type 2, see p. 207) of tuberculous arthritis of ankle joint. Note general decalcification except in the subarticular bone and blurring of the articular surface.

shaft This is denser than normal bone and shows no organised cancellous structure It resembles the spina ventosa type of dactylitis (see Figs 92 B and 90).

With osteoporosis at the lower end of the tibia the radiographs often show in the early stages an apparent increase in the density of the epiphysis and later some blurring of the articular outline (see Fig 172) For other types see p 71

A Brodie's Abscess usually involves or is in close proximity to the epiphyseal line The margin may be fairly well defined, the surrounding bone showing some sclerosis

In the adult the extremities may appear to have kept up relatively normal growth for size but they show a delicate open cancellous reticulation, whereas the shafts are bent and reduced to the thickness and appearance of a compact rod ¼ to ⅜ inch in diameter.



FIG. 158. Radiographs of the legs of a youth aged 20 years. Note the bent compact rods of the shafts and the expanded rarefied extremities. Osteogenesis imperfecta tarda.

as in Fig 157,B Fig 158 shows the characteristic appearances in the surviving adult For General Discussion, see p. 547

In Chondro-osteo-dystrophy multiple nuclei for the epiphyses and irregularity of the extremities of the diaphyses are seen in the radiographs in early childhood. Pressure of the body weight on the disorganised growing bone results in hortening of the limb and expansion of the extremities of the bones (see Fig 159).

It is from the upper and lower extremities of the diaphyses of the tibia and fibula that Multiple Exostoses (see Fig 160) and Chondromata frequently develop to their greatest size, and these may seriously hinder movements of the involved limbs *Jones* and *Lovett* state "The complete removal of these masses should be performed even in the growing epiphysis if they give rise to symptoms. Examination of a large number of radiographs of such cases shows that the exostoses grow from the diaphyses and not the epiphyses, which always appear to be free Pressure atrophy of the fibula leading to marked localised thinning and bending may be produced by an exostosis growing from the adjacent tibia.

involucrum which in the course of a month develops into a dense and massive bone three or four times the normal thickness. The signs and symptoms usually gradually fade and in the course of a few years the bone has developed normal characters. The causal organism is not known. The reaction, as illustrated in Fig 177 A and B is similar but more extensive than in the *chronic abscess; compare with Fig 170*



Fig. 175. Brodie's abscess in lower end of tibial diaphysis. The linear periosteal accretions indicates recent reactivity



Fig. 176. Brodie's abscess in upper end of tibia diaphysis with dense massive reaction extending to lower third of shaft. Recent periosteal accretions. Type of reaction seen in the so called "osteoid osteoma."

The reaction seen in some infants with tuberculosis of bone resembles it see Fig 90

Chronic Osteomyelitis of the tibia may result in marked sclerosis of the shaft of the bone. This sclerosis may be uniform throughout the bone simulating chalky bone in density but without the characteristic shape of the latter and ivory hard instead of brittle see Fig 176 or it may appear to be somewhat irregular in its distribution, though the irregularity and thickness of the cortex of the shaft is not so marked as in syphilitic osteoperiostitis (see Fig 9* A and Fig 170).

In other cases profound decalcification occurs. The expanded involucrum becomes lace-like (see Figs 178, A and B).

Marked hypertrophy of the anterior *cortex is seen in the aged in health. This is* not at the expense of the medulla which shows coarse cancellous tissue

which gradually blends with the density of the remainder of the shaft. The new periosteal bone This is laid down in a regular manner and its borders a The new periosteal bone may appear only as a thin line along the shaft in t the abscess or it may be markedly thickened (see Figs 174 and 175) This c



FIG 173 Radiograph showing a Brodie abscess in the lower end of the tibia in a girl aged 14 years. Duration of symptoms 5 years



FIG 174 Brodie s abscess of the lower end of t tibia with more extensive bone changes lower third of the shaft of the left tibia fo osteomyelitis on the left side. Note the thickening and sclerosis of the periosteal ne of the lower third of the tibia. On the rig note the rounded area of rarefaction in th end of the tibial diaphysis with sclerosis neighbouring bone which gradually blend the density of the rest of the haft. On th side there is no evidence of periosteal new b

the age of the absces and the reaction produced by it In some cases a reaction, by a dense expansion of the bone extends for a considerable distance from which remains within as a fairly well-defined decalcified area The lesions have periods of greater activity—these are indicated by further subperiosteal of bone (see Fig 176) This is the type of lesion which from histological tions of the focus has been styled **Osteoid Osteoma** (see general discussion The possibility of the abscess being due to the typhoid bacillus should not looked (see Fig 224) Irregular spicules of new bone not of the fine and delicate seen in periosteal sarcoma are seen on the lower third of the tibia in associa chronic varicose ulcers (see Fig 192 also p 191) **Chronic Sub-periosteal Absce** common on lower third of shaft (see pp. 224 and 061 and Fig 225).

Acute osteomyelitis does not produce radiographic signs for at least a weel infant the reaction develops and heals quicker and is relatively greater in ex in the adult.

In some cases the serial radiographs may show a reaction with a linear



Fig. 178A. Radiograph of chronic osteomyelitis of the left tibia. Note that the original shaft has been absorbed within a lace-like involucrum, and that there is pressure atrophy of the adjacent fibula. A small subperiosteal focus is shown in the middle one-third of the right fibula.



Fig. 178B. Radiograph of profound osteoporosis of the bones of the right foot in the same case of osteomyelitis as Fig. 178A.

Osteitis Deformans. The tibia may be the first bone to show the disease It may remain as an isolated lesion for many years To the clinician the forward bending of the tibia in the adult is suggestive of **Paget's Disease.** The radiograph shows a typical appearance of the deformed bone (see Fig 475 A and B and general description on pp. 600–15)

Tumours. A simple tumour of either bone may by its expansion and pressure cause absorption and even fractures of the neighbouring bone The *commonest tumour* of the tibia and fibula is the osteoma in cases of **Multiple Exostoses.**



Fig 177A. Osteomyelitis in newly born 31/7/39



Fig 177B. Same limb 16/5/39 Note massive and dense reaction in tibia but lessened involucrum to fibula.

In von Recklinghausen's Neurofibromatosis, fibromata may develop beneath the periosteum and structures simulating cysts may be shown on the radiograph. This has been illustrated by *Brooks* and *Lehman* Metastatic subperiosteal abscess may produce a similar appearance

Polycystic Dysplasia (Osteitis Fibrosa Cystica Localisata). Localised multilocular cysts may involve much of the shaft of one or multiple bones one extremity of the shaft or a peripheral segment near to the diaphyseal extremity—the latter lesion "migrates" away from the metaphysis with the growth of the bone *These localised* surface juxta-metaphyseal growth defects have been subjected to histological examination and variously interpreted. They are not known to be associated with any clinical significance other than, when involving a large segment, the possibility of fracture. Localised resection, if not complete may permit of redevelopment of cystic focus (see Fig 170). They tend to shrink during adolescence

Polyostotic Fibrous Dysplasia This may show as (1) a generalised fibrosis of bone in which there may be evidence of proliferation of cartilage as in Fig 180 (2) as a condition localised to one side of the skeleton or one bone as in Fig 181 or (3) isolated expansions of bone resembling but denser than the simple bone cysts (see Fig 182). For General Discussion, see p. 571

An appearance similar to this in the lower third of the fibula but with involvement of the tibia at the same time in a child 2 years of age was diagnosed from the clinical appearance as a sarcoma but the parents refused to allow amputation Local resection of the fibula and curetting of the tibia was done and portions of the



FIG. 182. Polyostotic fibrous dysplasia, isolated lesion.

FIG 183. Metastasis in tibia secondary to squamous-celled carcinoma of cervix. (Histologically reported a adamantinoma.)

material were histologically examined and reported as a chondrosarcoma. In spite of this th bone has consolidated and now 10 years later the tibia is consolidated and the child does not complain of any disability The lesion was a simple chondroma.

Holden and *Gray* have reported the clinical details with radiographic illustrations of a tumour which gave the histological appearance of an adamantinoma but which on radiographic examination presented an appearance resembling that of osteitis fibrosa cystica localisata.

The cystic condition of the bone was in the lower third of the tibia above the plane of the epiphyseal line and in this way differed from the common site of osteoclastoma. The patient a woman of 36 years of age had a contusion of the part 2 years previously A local recurrence occurred 2 years after a local resection of the tumour tissue



Fig. 179 Osteitis fibrosa cystica localisata.



Fig. 180 Polyostotic fibrous dysplasia general (see Figs. 63 and 472).



Fig. 181 Radiograph of a case of unilateral polyostotic fibrous dysplasia.

Giant-celled Tumours (Osteoclastomata) are frequently seen at the upper and lower ends of the tibia and fibula, being most common in the tibia. At the lower end of the



Fig 185. Chondroma of the lower end of the fibula. Note the soap-bubble-like appearance. It was excised and a bone graft inserted. 6 years after the fibula looks normal



Fig. 186. Hydatid cyst of tibia (verified).

tibia the tumour tends to show an absence of central trabeculation, whereas in the upper end and in the fibula the characteristic soap-bubble appearance of the tumour is more common (see Figs. 86 212 218) See General Discussion, p. 608

A **hæmangioma** of the tibia was seen (in a youth) in which the radiograph showed an expansion of the lower third with coarse trabeculæ radiating from a central focus The segment of bone containing it was resected by *Naughton Dunn*, a bone graft was inserted, and the patient recovered normal function of the limb *Pohl* has recorded a cavernous hæmangioma of the tibia (see also Fig 493).

Hydatid Cyst of Bone The tibia is one of the most frequent sites. The radiographs show the cortex of the bone scalloped and excavated in a regular manner from within. Later breach of continuity may occur producing irregularity of periphery (see Fig 186)

Simple Cyst of the tibia is illustrated in Fig 187 A and B These lesions develop at the extremity of the diaphyses They may affect but a segment of the periphery of the diaphysis and show the migration up the shaft as in Figs 84 A and B

Baker and *Hawkesley* illustrate a case of primary adamantinoma of the tibia which occurred in a man of 46 who gave a history of injury to the part 10 months earlier The radiograph shows expansion of the lower third of the tibia, as in early myeloma, with destruction of the cancellous tissue and thickening of the periosteum. There is no evidence of spread of the tumour away from the localised area of erosion

A localised well-defined ovoid area of destruction of upper third of tibia (1½ inches long) with but a thin bony wall remaining was reported as an Adamantinoma. The histologist confirmed this but later it was proved to be a secondary from a primary squamous celled carcinoma of the cervix uteri (see Fig 183)

Chondromata of the lower third of the tibia or fibula in *Ollier's* type of chondrodystrophy have been seen in which the radiographic appearances somewhat resembled



FIG. 184 Hyperparathyroidism. Isolated cysts in bone showing general decalcification.

the appearance of Osteitis Fibrosa Cystica Localisata. Polycystic dysplasia and polyostotic fibrous dysplasia must be distinguished from the cystic lesions in hyperparathyroidism The latter is a generalised disturbance of metabolism which produces osteoporosis of a characteristic nature in all bones of the skeleton, with localised cysts in one or more bones *Kienböck* and *Grünspan* illustrate the radiographic appearance of a tumour which was diagnosed histologically as a Fibro-endothelioma. The radiographs show a multilocular cyst like destruction of the upper half of the tibia with erosion of its outer wall which had resulted in a spontaneous fracture The patient a youth of 21 gave a history of pain for one year



Fig. 188. Sarcoma of the lower half of the tibia. Note the increased density of the shaft compared with the epiphysis, the fine periosteal spicules which are absorbed at the primary focus near the lower end, and the flaky calcium deposits in the swellings of the soft tissues in this area.



Fig 189 Calcified cysticerci in soft tissues of leg

Localised calcifications and ossifications in the tendon sheaths are occasionally seen. Fig 190 shows well-developed ossicles in the region of the tendo Achilles in a patient

Sarcoma. Sarcoma of the lower thirds of the tibia and fibula is of not infrequent occurrence The radiographic appearance of one type is well illustrated in Fig 188. It shows temporary sclerosis of the shaft of the tibia and obliteration of the trabeculation. *Sharply defined periosteal spicules are shown at right angles to the shaft of the bones*; these have been absorbed at what appears to be the primary focus of the tumour on the



Fig 187A. Radiograph of simple cyst t lower extremity of the tibia (28 7 36).



Fig 187B. Radiograph of simple cyst at *lower extremity of the* tibia (21 9 39), showing the progress of the cyst into the shaft due to the growth of new bone

inner side of the lower third of the tibia. The epiphysis does not show any bone change and as yet the tumour has not involved the fibula The upper end of the tibia is one of *the commoner sites for the development of the sclerosing sarcoma. The first indication* of the tumour is an ill-defined area of increased density with perhaps little or no periosteal reaction. As the malignant cells invade the adjacent bone the area of density extends and some periosteal accretion of new bone may appear (see Figs. 193 2A and 2B). Prompt amputation failed to prevent metastases in one case recorded by the author [44] Biopsies in two other cases recorded failed to reveal malignant nature of tumour

Shadows in the Soft Tissues of the Leg. Small ovoid bodies about ¼ to ⅜ inch long of the opacity of bone are occasionally seen in the soft tissues of the calf These are the *calcified cysts of cysticercus cellulosæ* (see Fig 189).

Calcified guinea worms have been illustrated by *Cannor*

Following phlebitis organisation and calcification of thrombi in the veins may occur and radiographs will show these calcified thrombi of varying lengths, but of fairly uniform thickness. The posterior tibial artery may be seen on the lateral radiograph when it is calcified a a shadow about ⅛ inch thick behind the shadow of the tibia.

who had tabes dorsalis a Charcot's hip joint and Paget s disease of the os calcis Irregular calcium deposits are shown in Fig 191 which indicate the site of a fibro-sarcoma

Varicose Ulcer may be present for years without any associated bone changes but in some cases localised periostitis is denoted by irregular accretions and spicules (see Fig 192) of periosteal new bone (which have been interpreted wrongly as evidence of sarcoma) localised osteitis with destruction may follow and more rarely epitheliomatous changes

Tropical Ulcer In some of these lesions similar changes to those described in

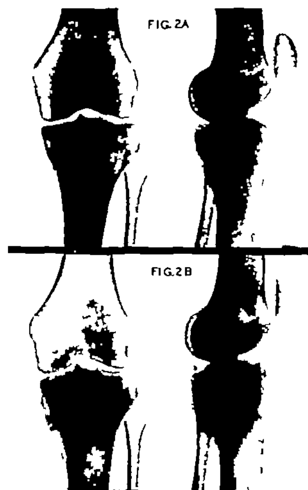


Fig 193. Sclerosing type of sarcoma, upper end of tibia (fatal).

varicose ulcer are met with In others a more extensive inflammatory reaction in the acute stage occurs which resembles the radiographic appearances of the second type of osteomyelitis which is described on page 221, Fig 220 The condition sometimes reaches epidemic significance as in Assam and areas with damp hot swamps The ulcers develop chiefly on the dorsum of the foot and the legs less frequently on the hands and upper extremity The causal organism has not been determined though some heal within a short time others become chronic and persist for many months The extent of bone involvement can only be determined by radiography



FIG 100. Radiograph showing four isolated ossicles in the region of the tendo Achilles in a tabetic patient with Paget's disease (see Fig 287).



FIG. 101 Radiograph showing irregular calcium deposit in a fibro-sarcoma which involved the tendo Achilles.



FIG 102. Irregula coarse spicules of periosteal new bone associated with a ricose ulcer

It has been shown by *Nordheim* and others that if traction is applied to a limb the articular surfaces are separated and a linear transparency (? vacuum) can be demonstrated for a short time between the opposing surfaces. It apparently disappears as the space is obliterated by fluid and cannot be demonstrated in joints with effusion. *Nordheim* demonstrated it in the interphalangeal, shoulder and hip joints. In the knee joint it can readily be shown by manual traction on the leg, more commonly on the inner aspect of the joint than the outer.

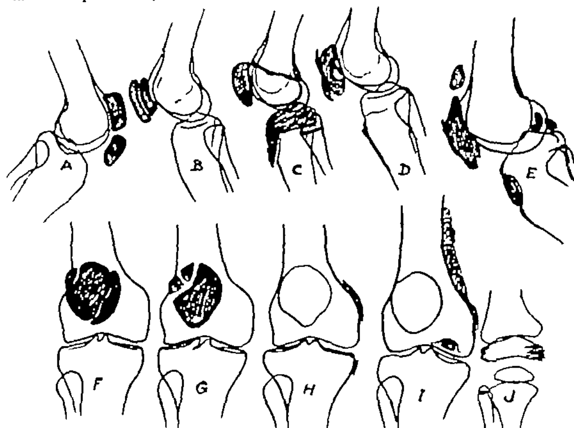


Fig 193. Tracings of radiographs of abnormalities of the patella and knee joint.

A. Double patella—bilateral (*Petty*).
B. Double patella—bilateral (*Haenisch*).
C. Double patella—bilateral and *Osgood-Schlatter's* disease.
D. Exostoses on anterior surface of patella. Also cyst-like changes in the patella.
E. Loose bodies in the knee joint, also spurs on the patella. Note also that the tibial tubercle is represented as a separate ossicle—this was bilateral.
F. Tripartite patella—bilateral.
G. Tripartite patella—bilateral.
H. The so-called *Stieda* or *Pellegrini-Stieda* fracture associated with a linear shadow on the inner side of the tibia.
I. The *Stieda* fracture which appeared together with an ossifying haematoma on the inner side of the lower third of the femur about six weeks after an unsuccessful attempt to remove the loose body—osteochondritis dissecans.
J. Irregular medial and to a lesser degree lateral margin of epiphysis of the lower end of the femur—normal.

OSSIFICATION

The bony nucleus of the epiphysis of the lower end of the femur is usually present at birth and its presence is used in medico legal procedures as an index of viability or

CHAPTER IX

THE KNEE JOINT

Technique Radiographs of the knee joint are usually made in the antero-post and lateral planes For radiography of the patella the lateral and postero-anterio preferable, and these should if possible be supplemented by a radiograph taken the patient lying prone and the leg acutely flexed with the central ray directed the patella. The latter view often provides evidence which is absent on the other v For the localisation of loose bodies and the determination of the nature of bone li in the neighbourhood of the tibial spine stereoscopic radiographs may be extre valuable Various methods have been devised for showing up the outline of the capsule and the semilunar cartilages These involve the injection of a gas or op fluid (lipiodol thorotrast abrodil, etc.) or both into the joint cavity By inje about 2 c c of a specially prepared contrast fluid into the joint and dispersing it thre out by a few movements of the limb, *Bohm* has demonstrated that the out of the internal structure can be sh *J Oberholzer* injects oxygen before 1 of perabrodil. This visualises all ligan and capsule.



Fig. 194 Radiograph howing marked thickening of the soft tissues superficial to patella and tibial tuberosity in bursitis.

Using a "soft" tube it is possib some cases without injection, to show only the outlines of the ligaments atta to the patella but also its cartilag envelope and the anterior boundari the joint capsule **Forward Displace** of the **Patella** may be shown in effu while in haemarthrosis the anterior out of the distended capsule may als visible. **Chronic Bursitis** may be indic by a marked increase in the soft t shadow anterior to the patella and ligaments—these soft tissues show in *lateral radiograph as a band of homoge* density upwards of 1 inch thick, pas from the tibial tuberosity to the u limits of the anterior border of the pat the tissue bounded by the patella al and its ligaments below and the ant surface of the bones posteriorly being lesser density and affording a contrast of demarcation (see Fig 194)

When the presence of a **Loose Bo** suspected, but is not shown on the ordi radiograph a further antero-posterior radiograph using a curved film against the l of the flexed knee and with the central ray directed to the intercondylar space, may s it

Haenisch has recorded a bilateral double patella in which the one bone is anterior to the other the anterior being the larger and possessing a posterior concave surface which articulates with the anterior surface of the posterior patella (Fig 105 B)

A common abnormality is a **Bipartite or Tripartite Patella** in which the bone appears on the antero-posterior radiograph to have a fragment broken off its supero-lateral extremity—this fragment may be single or it may show fragmentation On the lateral radiograph a typical cleft is shown in the middle third of the bone as in Fig 106

One bilateral example was met with in which the patella showed a crescent shaped bone separated from the entire medial border as well as a separate fragment from the lateral extremity of the upper border (see Fig 105 F). The bony abnormality is discovered on radiography of the knee joint, undertaken to ascertain the cause of recurrent effusion or attacks of pain in the joint.

Potenza illustrates a case of **Tripartite Patella** in a patient who had successfully collected damages from two companies on the erroneous interpretation of the radiographic appearances as those of fracture

Congenital Subluxation or **Dislocation of the Patella** may show a familial distribution and is often associated with such congenital anomalies as congenital dislocation of the hip or club foot etc The patella is usually displaced laterally and the lower end of the femur shows alteration in its axis and its surface for the patella.

Cases of **Recurrent Slipping** or dislocation of the patella occur in association with flattening of the articular surface of the femur particularly on the outer condyle, an appearance which suggests osteochondritis *Zanoli* has described 13 cases of patellar dislocation Congenital dislocation of the knee joint itself is also seen *McFarland* reported 4 cases and referred to 127 cases which had already been described in the literature *Baldwin* illustrates the condition in a baby 2 days old The dislocation was reduced. At this time no patella could be felt, but at 8½ years the patella appeared to be of normal size—the lower extremity however did not appear to be fused with the upper

Fairbank[4] has illustrated subluxation of the tibia and defective development of the fibula in which at operation he found that the crucial ligaments were completely absent

A separate ossicle may be present for the tubercle of the tibia (see Fig 105 E) or this may be formed by a downward projection from the epiphysis of the upper extremity of the tibia. In some cases this downward projection has the appearance of fragmentation (see Fig 105 C).

The presence of a sesamoid (the **Fabella**) in the outer head of the gastrocnemius should not be forgotten. To the inexperienced, on the lateral radiograph this appears as a foreign body which is lying in the popliteal space and attempts have been made to extract it It may sometimes be seen on the antero-posterior radiograph of the knee joint as a small ossicle to the side of the lateral condyle of the femur It is found in about 23 per cent of adult knee-joint radiographs not always bilateral. Fracture has been recorded

In the condition of **Peripheral Dysostosis** radiographs showed defective development of the lateral aspect of the proximal tibial epiphysis associated with lateral displacement of the patella (see p 29). The patellæ may be small or absent.

Injury Following injury in the neighbourhood of the knee joint no alteration or damage may be seen on radiographic examination for several weeks After this interval the radiograph may show irregular osteoporosis of the patella or the condyles of the femur in the form of multiple, fairly well-defined, rounded areas of rarefaction in bone of normal density an appearance which may be interpreted as indicating grave pathology

maturity of the fœtus. The patella probably shows a greater range of time in the appearance of its nucleus than any other bone in the skeleton. It may appear during the first year of life, but its ossification may be delayed until puberty It is usually present in girls at the age of 4 to 5 In some cases more than one nucleus can be shown on the radiograph The ossification of the upper epiphysis of the tibia and fibula is described in the chapter dealing with those bones. The sesamoid in the head of the gastrocnemius does not usually appear until puberty The frayed appearance of the medial surface of the femoral epiphysis in the infant is a normal one and should not be interpreted as erosion of the epiphysis which its appearance somewhat suggests. An interesting radiographic study of the ossification of the patella has been published by *Hans Hellmer* [1] Patella defects are seen in association with iliac horns

Congenital Deformities. Congenital deformities of varying severity are seen—a number of these have been indicated in previous chapters

Patella. The patella may be absent. It may be represented by a relatively small bone Cases of congenital absence of the patellæ have been reported in association



FIG 196. Bipartite patella. On the antero-posterior radiograph note the separate fragment on the lateral side of the upper part of the bone and on the lateral radiograph the cleft in the middle third.

with arthrodysplasia of the elbows and dystrophy of the nails A case was illustrated by *Petty* showing a bilateral double patella suggesting ossification from two nuclei which had never fused a gap of ½ to 1 inch existing between the two bones (see Fig 195 A). Osteochondritis dissecans may be seen in the articular surface

Long lateral and medial spurs may develop at the site of osteotomies of the lower third of the femur They are gradually absorbed The condition of diaphyseal aclasis does not develop

Displaced Internal Semilunar Cartilages. Displacement of the internal semilunar cartilage may not affect the appearance of the knee joint on the radiograph, but it is not uncommon to find that the joint space of the affected side is relatively diminished even in the case of recent displacement. With an older lesion the approximated condyles may show commencing osteoarthritic changes.

In some cases the damaged cartilage undergoes calcification, and it may appear on the radiograph as a loose body with an ill-defined margin. If the cartilage is completely displaced it may undergo complete calcification and the nature of the loose body shown on the radiograph becomes apparent.

Rupture of the lateral ligaments of the joint may be demonstrated radiographically by taking antero-posterior radiographs with the lateral or medial surface of the joint resting on a small sand bag the radiograph being taken from the side of the couch, the central ray being parallel to the top of the couch Widening of the joint space on the affected side is shown. Dislocation of the patella occasionally follows trauma and the radiographs in these cases frequently show appearances (knock knee) suggestive of rickets in childhood. Complete dislocation of the knee joint with forward or backward, medial or lateral displacement of the head of the tibia off the femoral condyles may occur as the result of trauma but it also occurs in cases of rheumatoid arthritis without any definite trauma.

Mitchell has illustrated 3 cases of anterior dislocation of the tibia and 1 case of posterior dislocation.

Ritter[1] described a complete forward dislocation of the tibia and fibula of a woman of 69 who slipped while walking

Osteochondritis Dissecans. Osteochondritis Dissecans is the term which was given by *König* to a condition which he thought suggested that a fragment of bone with its articular surface had been dissected out of the articular surface of the medial condyle of the femur As early as 1738 *Alexander Munro* had observed this condition and suggested that the separation of the loose body was due to trauma. This lesion is most commonly found between the ages of 16 and 25 years, but some cases have been discovered at an earlier and a later age the author found it in both knees of a man aged 47 years and in one man aged 66. The incidence is much greater in the male than in the female It is frequently bilateral, though one side only may show the clinical signs Though this lesion is most commonly encountered in the articular surface of the medial femoral condyle (often slightly posterior to the mid line) the author has observed it in the lateral condyle the patella, the femoral capital epiphysis, the capitellum the head of the radius, the humerus, the navicular the astragalus, the first metatarsal, and the lower end of the tibia. From a study of the serial radiographs and the operative findings in a number of cases, the writer's conception of the lesion is different from that usually described The lesion, he believes, is produced in the first instance by injury to a localised segment of the articular surface embracing either the cartilage alone or the cartilage and the subarticular bone It is possible that a breach in the surface permits the permeation of synovial fluid, and that this tends to inhibit fusion The affected fragment is not usually completely cut off from its blood supply in the young person it may continue to grow within the bed of the parent bone The radiographic findings vary with the extent and the nature of the lesion If the cartilage only has been injured the articular surface may appear to be normal later a small depression may be noted In this depression a small ossicle develops. In a boy aged 11 years, who gave a history

—tuberculosis or even sarcoma These discrete islands of osteoporosis are sometimes very marked during immobilisation of the leg after fracture.

Breitlander has illustrated this condition following insignificant injury His radiographs showed marked sub-chondral rarefaction which gradually disappeared after a course of physical "medicine" (see Sudeck's atrophy pages 82 and 83)

Longitudinal fissures of the patella occur of which no indication is obtained except on postero-anterior and infero-superior radiographs (as described at the beginning of the chapter). The importance of the latter is well illustrated in the radiographs used by *Lapidus* in a paper describing longitudinal fractures of the patella. These fractures should not be confused with the appearance of the bipartite or tripartite patella.

Free Fat in the Knee Joint after Injury *Holmgren* reported 65 cases of injury to the knee joint in which he was able in 20 to show the characteristic appearance of free fat in the lateral radiographs which had been taken with the tube at the side of the affected joint. The fluid fat is seen to float on the horizontal surface of fluid (blood) in the joint.



FIG. 197 Traction fracture of the tubercle of the tibia.

When the tubercle of the tibia is developed from a downward projection of the upper epiphysis of the tibia, this projection may be torn off by forcible flexion of the knee joint, as for instance in attempting forcibly to bend the knee of a patient incompletely anæsthetised and rigid (see Fig 197).

After an injury to the knee joint area a linear shadow may be seen lying parallel with the medial surface of the inner condyle of the femur suggesting the separation of a flake of bone from the surface of the condyle (see Fig 105 H)

As this appearance is not seen in all cases immediately after the injury it is in these cases probably due to ossification in damaged fibrous tissue in the medial ligament.

This appearance was first described by *Stieda* later *Pellegrini* published an account of a number of cases The condition is called the Stiedachen Fracture or Maladie de Pellegrini-Stieda. It does not produce any permanent disability The lesion was found by *Keen* in 17 of 280 Bantus who had sustained injuries to the knee. He found that the medial collateral ligament was larger in the Bantu.

A number of radiographs showing the typical appearance of this condition have been seen in patients giving a history of injury three or four weeks previously Similar lesions have been found in other sites, *i.e.*, over the malleoli, metacarpals, etc. Such an appearance was also seen along the medial condyle together with a band of ossified tissue along the inner side of the lower third of the femur following an unsuccessful operation for removal of the detached ossicle in a case of osteochondritis dissecans.

Radiographs illustrating the Stiedachen fracture are used by *Michelson* and also *Pertignani*

The development of cysts in the semilunar cartilage following injury may be associated with erosion of the articular surface. *H A T Fairbank* and *F I Lloyd* have illustrated these lesions in the external tibial condyle.

scalloping of the intercondylar space with similar but less well marked changes in the neighbourhood of the tibial spine Any or all of the articular surface may be somewhat flattened and irregular in contour The subarticular bone may show circumscribed areas of cancellous destruction which may be mistaken for evidence of tuberculosis. The joint space may be narrowed; there may be a suggestion of one or more loose bodies and the articular surface may show some sclerosis. The shafts show multiple transverse trabeculae The soft tissues around the joint may be increased The latter with hypoplasia of the shafts of the bone may give a spindle-shaped expansion to the joint which may be mistaken for tuberculous arthritis. The bones, however do not present the osteoporosis which would accompany lesions of this severity in tuberculosis (see Fig 199) (see also p 608)

In some cases the clinical and radiographic features have aroused the suspicion of sarcoma (see p 213).

Loose Bodies. Radiographs may show loose bodies in the knee joint apart from the condition known as osteochondritis dissecans and displaced semilunar cartilage.



Fig 200 Loose bodies in the knee joint. The antero-posterior radiograph shows only one in the middle of the joint The lateral radiograph shows one above the patella, one in front of the tibial spine and several behind

These loose bodies may be single or multiple, quite small or as large as a walnut. Only those which have undergone calcification or ossification can be shown Many appear to be formed of cartilage and cast no shadow on the radiograph. Small ill-defined shadows seen on the antero-posterior radiograph in the joint space between the opposing condyles of the femur and tibia may be due to partial calcification or ossification of the semilunar cartilage The loose bodies most commonly seen are ovoid in shape. They may be shown to alter their position by flexing the knee several times between the taking of different radiographs. They may take up any position in the joint capsule, their range of position being dependent on their size and number and the boundaries

of injury some weeks before radiographs showed a small indentation of the medial condyle at the typical site but no sign of an ossicle. Four years later further radiographs showed a much enlarged indentation within which an ovoid ossicle was present.

If the lesion is symptomless its discovery may be made by chance during the taking of radiographs for some entirely different reason, as when the joint is X rayed for comparison with the opposite affected joint. Unless the loose body is carefully sought for the condition may be overlooked because of the normal general appearance of the bone. When symptoms develop radiographs may reveal the ossicle a little denser than the parent bone (it is becoming avascular) or the latter may show a denser outline for its bed. If the radiograph is taken with the central ray at a tangent to the affected surface this may appear to be a little flattened and irregular. After the symptoms have persisted for some months radiographs may disclose that the denser fragment, in which the cancellous structure appears to be obliterated, is losing its sharp outline and uniformity of density while the bone surrounding its bed may show such marked localised osteoporosis that the suspicion of tuberculous caries may be aroused. It is the author's belief that the increased density of the ossicle and its subsequent changes are due to avascular necrosis, an opinion which is supported by the reactive changes that develop concomitantly in the surrounding bone. Removal of this dead fragment usually brings an end to the reactive changes in the surrounding bone and leads to its recalcification. In some cases such ossicles appear to have a rather different history. They are found in joints in which the epiphysis has developed from multiple ossific nuclei, as in hypothyroidism and chondro-osteo-dystrophy or in which the regenerating fragments of the epiphyses are injured and sequestrated, as in osteochondritis. Such separate ossicles are frequently seen in the second metatarsophalangeal joint following Köhler's disease and occasionally in the hip joint following *Legg's* disease.

The history of the fragment separated by trauma is similar to that of the bone graft, except for the special factors which operate on an articular surface. The fragment may undergo any one of the following four changes —

(1) It may fuse and become incorporated with, and indistinguishable from, the parent bone.

(2) It may be completely absorbed, leaving no trace of ossification in the gap which it filled.

(3) It may become necrotic and undergo what has been referred to as creeping substitution, in which it may lose the sharp internal definition of its structure, take on an added density and later the appearance of fragmentation, and, after the absorption of the denser fragments, may experience a regeneration and development which may be complete as in (1) or defective in part as in (2). the latter condition is probably due to trauma while the fragment was still plastic. These changes occur with concomitant decalcification and recalcification of the adjacent parent bone.

(4) It may fail to show any regenerative or destructive properties and eventually be extruded into the joint as a loose body (see Fig 108).

It is rare to find these changes in the lateral condyle but similar changes are found in the opposite femur although they may give rise to no symptoms. Somewhat similar changes are also seen in the lateral femoral condyle, but the writer has found these only in association with recurrent slipping of the patella.

The loose body is not always a regular ovoid, for irregular absorption of the calcium in the detached bony fragment may result in a shadow having irregular borders, or even presenting a flaky appearance. It may appear to involve a large area of the articular surface. It has been misinterpreted as evidence of tuberculosis. In the early stage of some Charcot joints a large portion of the articular surface may be detached

he shafts of the femora appear as slender bent rods of compact bone showing little or o evidence of a medulla, but having rarefied expanded cancellous extremities The steomalacic type of syphilis presents a radiographic picture in infancy which may be o like those seen in osteogenesis imperfecta that the two conditions must be considered efore arriving at a diagnosis



FIG. 217 Osteogenesis Imperfecta



FIG. 218 Radiograph showing general coarseness of the bone trabeculæ of the left side of the pelvis and upper half of the femur and increase in density The bones of the pelvis show pressure deformities, the pelvis is flattened and the walls of the acetabulum are being pushed into the pelvis. The transverse fracture of the upper end of the femur is characteristic of Paget disease of bone.

Syphilis of the femur in the infant may show lesions similar to those described in the tibia (see Fig 163 p 175)

The dense club-like expansions of the upper and particularly the lower thirds of the femur seen in radiographs of chalky bones (**Albers-Schonberg s Disease**) cannot be mistaken for any other condition. The appearance is similar to that illustrated in the tibia (see Fig 162)

Expansion of the lower third of the femoral shaft to the form of a tapered wine bottle is seen in **Gaucher s Disease** some cases of **Hyperthyroidism**, and also occasionally in disease of the hip joint

occurs The condition is most commonly found in boys between the ages of 18 and 15 years, following injuries received in the sports field.

Diagnosis The patient seeks medical treatment because of pain on attempting to flex fully the knee, or to bend down and pick an object off the floor There is usually a history of a recent injury

On examination, a swelling, which in some cases is associated with effusion, may be seen in the region of the tibial tubercle. Pressure in this region produces pain, and though the patient may be able to walk, he suffers pain when he attempts to flex the thigh when sitting Radiographs of the affected knee joint will usually show that the epiphysis of the tibial tubercle is not fused with the end of the diaphysis, and its borders are *irregular* or even *fragmented* *Similar irregular ossification may also be noted at* the lower pole of the patella.

The writer has not observed the same series of changes in the damaged structure as he has described in osteochondritis in other sites.

It is on the clinical rather than on the radiographic appearances that the diagnosis must be made, for similar appearances are often found in the radiographs of the unaffected knee.



Fig. 109 Radiograph of haemophilic knee joint showing excavation of tercondylar space changes in the head of the tibia and irregularity of the rticular surface

Treatment. In the severe form, conservative treatment, including complete immobilisation of the knee joint for six to eight weeks, will usually suffice to free the patient from the pain, and, if the radiographs have shown localised osteoporosis, or fragmentation of the bone, all strain on the patellar ligaments should be prevented until the radiograph shows that these conditions have con solidated.

In the milder cases, *Schlatter* recommends "a tightly applied criss-cross strapping of adhesive plaster extending around about two-thirds of the circumference of the leg and applied from perhaps 1 inch below the tubercle to 1 inch above the lower border of the patella has proved a satisfactory method. This is renewed as it becomes loosened, perhaps every ten days, for about a month, and a flannel bandage worn for a few weeks after this.

In **Osteochondritis of the Patella** the radiograph shows an alteration in the regular contour and trabeculation of the inferior extremity The out line of the inferior angle may be blurred and irregular and its structure may show islands of condensation in a matrix of rarefied bone

The condition was first described by *Sinding-Larsen* [1] in 1921 in two otherwise healthy girls of 10 and 11 years. It was associated with pain in the knees. The condition healed in about 1 year

Johansson [2] described further cases.

Hanley and *Griswold* illustrate examples of this condition in three boys aged 12 years of age and two girls of 12 and 13 years respectively

Haemophilic Joints. In a knee joint which has sustained several haemorrhages, definite bone changes may be shown Amongst the most prominent are progressive

Osteitis Deformans of the femur may involve the whole or part of the shaft When a fracture of the shaft occurs in osteitis deformans it is always transverse as in marble bones *i.e.*, it breaks like a stick of chalk (see Fig 218) The commonest sites are the subtrochanteric area and the femoral neck (see p 210)

In **Ollier s type of chondrodystrophy** the femoral shaft may show cortical crater-like structures or lines of rarefaction radiating to the extremities from the neighbourhood of the nutrient foramina These are due to an irregular proliferation of cartilage (see Fig 219).

Osteomyelitis of the femur in the acute stage may show no alteration in the radiographic appearances. The first may be a small area of decalcification of the cortex near the growth cartilage In some streptococcal cases rapid rarefaction of the bone may be seen after an interval. The staphylococcal type frequently leads to destruction of the whole or part of the shaft by separation of the periosteum and the formation of a sequestrum. The sequestrum, not being in communication with the blood stream, retains its calcium content so that the radiographs show rarefaction of the living bone but normal density of the sequestrum. In contra distinction to the tuberculous sequestra, which have an amorphous structure the sequestra in staphylococcal osteomyelitis have a normal bone structure and very clearly defined margins—they are as sharp as a broken piece of rock—within the rarefied new bone

Nathan is of the opinion that staphylococcal infection is much less frequent in the acute osteomyelitis of the upper end of the femur in children than streptococcal and pneumococcal.

The middle third of the shaft of the femur is one of the sites for the development of a destructive osteomyelitis Infection is conveyed *vid* the nutrient vessels It may be so virulent that the area of bone supplied and infected may be killed with its periosteum. Accordingly this area will not alter in its radiographic appearances for some time The periosteum of the *neighbouring bone will react and* a varying amount of sub-periosteal new bone will be laid down. As the boundary of the living periosteum is not likely to be at one level the new bone may give the cortex the appearance of localised pressure absorption Later the necrotic bone may show an increased density due to attraction of calcium or having lost its fibrous element may fracture spontaneously be gradually absorbed or undergo gradual substitution. In other cases where the infective agent is not so virulent a **Chronic Osteomyelitis** of the middle third of the femoral shaft is induced, which may be mistaken for sarcoma (see Fig 220).



FIG. 220. Osteomyelitis of femoral shaft Note irregularity of periosteal reaction.

In such a case within the course of the second month of the onset the middle third of the shaft may show general derangement of its architecture, some increased density and a woolly periosteal deposit of new bone which gradually tapers and peters out as it approaches the upper and lower one-thirds of the shaft

Fischer has illustrated a number of cases of Gaucher's Disease in which this expansion of the lower third of the femur is present

C M Riley and *H Schwachman* described the clinical findings radiographs and photographs of a boy aged 4 years 11 months and a girl 4 years 10 months with fusiform expansion of the lower half of both femora and similar but less marked changes in the long bones of the leg and forearm. Both had anorexia ankle clonus and hyper reflexia, but there were no abnormal laboratory findings

Pyle describes a very unusual appearance in the long bones of a boy 5 years of age The doctor was consulted because of knock knee; there was no history of any severe illness All the long bones particularly the femora, showed expanded extremities—in shape the bones resemble the bones of Albers-Schonberg's Disease when the condition



FIG. 219 Irregularity of ossification of the bones of the pelvis and femora due to proliferation of cartilage Five years later radiographs showed multiple densely calcified islands in the osseous defects, see Figs. 100 and 120. *Ollier's* type of chondrodystrophy but definitely bilateral

is fully developed, but in this case of *Pyle's* the bones showed no compact tissue except a little in the narrow waist of the shafts The appearance of the long limb bones rather resembles also the appearance of the proximal phalanges and metacarpals in Cranio-cleido-dysostosis. In the type of Osteitis Fibrosa Cystica which is associated with a parathyroid tumour the femora may be bent may show marked osteoporosis with absorption of the compact periphery cyst-like changes in the medulla, and sometimes pseudo-fractures

Pathological fractures of the femoral shaft may occur in several bone diseases such as Osteitis Fibrosa Cystica Hyperparathyroid, Osteitis Deformans Osteogenesis Imperfecta, Paralysis Osteomalacia, Marble Bones (Albers-Schönberg), and in localised bone destruction due to Simple Cyst, Polycystic Dysplasia and Polyostotic Fibrous Dysplasia, Subperiosteal Angioma or Chondroma, Sarcoma and Secondary Malignant Metastases There may be no demonstrable bone changes in Tabes.



Fig 222A.



Fig 222B.



Fig. 222C.

Fig 222A. Fracture (septic) of the middle third of the femur with separation of a sequestrum. Note the bridge of callus between the two fragment and the relative density of the sharply outlined sequestrum.

Fig. 222B Bismuth past injected into the sinus, showing that it completely encircles the sequestrum.

Fig. 222C Photographs of the extracted sequestrum, showing that the sharp fracture surfaces are preserved

During the second and third months the middle third undergoes decalcification and dissolution its cortex and involucrum may be broken in parts and fragments of it may be shown carried into the surrounding soft tissues. The involucrum over the middle third is now much thicker it may reach the thickness of the shaft over the central area of the focus. Though of lesser density than the decalcified shaft and somewhat woolly in appearance, it has a fairly regular peripheral border It gradually tapers to the extremities of the shafts to which it has gradually spread. During the fourth month evidence that the active process has ceased and resolution has begun is indicated by some increased density and definition of the involucrum and the signs of sequestration



A. B. C.

Fig 221 A Acute osteomyelitis, 9 12 44 (onset 19 11/44). B. 4/1/44 disintegration. C 6 2, 45 displacement multiple sequestra formation with coxa vara deformity of plastic bone

of bone fragments. With succeeding months this bone increases in density marked sclerosis of the area which has foci of disintegration and sequestra may remain to indicate *the site for many years (see Fig 221 C)*

Useful information as to the extent of a sinus and the portion of bone involved in it may often be obtained by the **injection of opaque material into the sinus.** Lipiodol is sometimes used, but this and other liquid injections are not satisfactory as they cannot be forced into the ramifications of the sinus. A mixture of 25 per cent. of lipiodol in soft paraffin, or better still, 25 per cent. of bismuth carbonate in vaseline, is the best medium for this purpose The method used is to mix the bismuth with the vaseline which is then heated for sterilisation. After this it is stirred and completely mixed then when it is cooled sufficiently for the bismuth to remain in suspension it is drawn up into a large syringe of about 50 cubic centimetres capacity the barrel of which is provided with two rings at the top so that firm pressure can be applied to the piston. The mixture is allowed to cool down until it forms a thick paste The nozzle of the syringe is put into the sinus and sterile dressings are held firmly around it and against



Fig. [illegible]. Chronic typhoid abscess in the shaft of the femur

the skin surrounding the sinus. Pressure is then applied to the syringe and the mixture in a semi-solid core is forced into the ramifications of the sinus radiographs in various planes are then taken. It is advisable to carry out this examination shortly before the operation (designed to clear up the sinus) is done. This will enable the operator to trace the course of the sinus and will prevent any reaction in the limb which might arise from blocking up the sinus (see Figs. 222 A, B and C)

In the chronic case massive new periosteal bone formation of greater density may obscure the outline of the embedded sequestra. If no sequestra are found, or if they have been evacuated, the whole shaft on healing may become as dense as the bones in **Albers-Schönberg's Disease**, but it retains its normal shape it is extremely hard and does not readily fracture and being a localised lesion can readily be distinguished from the condition of marble bones

Localised streptococcal infection of the femur may show on the radiograph as an area of cortical erosion which gradually extends. Only a little swelling of the soft tissues may be present the patient's attention is drawn to the condition by local pain and tenderness On the other hand it should be remembered that acute streptococcal infection of the bone may show no change in the radiographic appearance for a week or more after the clinical symptoms have been prominent. Later the radiograph may show very extensive bone destruction.


FIG. 223 Septic fracture of the femoral shaft Gun-shot wound. Not the large collection of gas due to anaerobic infection on the inner side of the femur

Infective processes within the shaft of the femur may stimulate the growth in length of the bone, but in those cases in which the metaphysis is involved growth may be checked (see Figs. 101A and 101B and Fig 215).

In the early days of the European war of 1914–1918 one saw collections of gas in the muscles of limbs which had been injured by bullets or shrapnel These gas collections one found always associated with anaerobic infection of the wounds, and though at operation on many of these cases the surgeon failed to detect collections of gas, the bacteriologist always found anaerobic organisms in his cultures from the tissue or foreign body removed. One was able in this way to demonstrate that radiographs provided within a few minutes the earliest positive evidence of gas gangrene. Thus operative procedures could be conducted immediately to the great benefit of the patients (see Fig 223). If the superficial fascia is damaged by the trauma air may be forced beneath it and appear on the radiograph like bubbles of gas. Their presence on radiographs taken soon after the accident permits of identification. In cases of doubt by repeated radiographic examinations at hourly intervals increase in the gas bubbles will be shown in gas gangrene.

Periostitis, Brodie's Abscess and Gumma present the appearances described elsewhere (see pp. 053–63) Fig 224 shows the appearances of a chronic typhoid abscess.

Subperiosteal Abscess. *The upper third of the medial aspect of the femoral shaft* is one of the more common sites for this lesion It is indicated by a small rounded area of transparency perhaps only ¼ inch in diameter surrounded by a dense thickened zone of subperiosteal new bone which spreads up and down the shaft in a spindle-shaped form (see pp 178 183) Some authorities regard this inflammatory lesion as a simple neoplasm—osteoid osteoma (see also Fig 430)

Bone Cysts. Simple bone cysts may be discovered by the radiologist when examining

a radiograph of a fractured limb. They occur most frequently in the region of the trochanters and femoral neck. They may be simple or multilocular The latter may extend after attempts at evacuation The bony wall of the cyst may in part be destroyed without fracture occurring (see Fig 220, A)

These simple bone cysts may cease to develop and undergo progressive calcification This appearance has been seen in a woman of 30 and a man of 70 The former I had under observation for 7 years The cyst was accidentally discovered on a radiograph of the pelvis, including the intertrochanteric area of the femur in which it had



Fig. 227A. Multilocular cyst of femur

developed Fracture through the cyst or surgical evacuation usually results in obliteration of the cyst. A fracture of the neck of the femur through a solitary cyst in the bone in a boy of 6 years was described by Edwards

These simple bone cysts may commence to develop at any age One such cyst was seen in the neck of the femur of a child 3 years of age.

Multilocular Cysts A common site for localised multilocular cysts is the shaft in the intertrochanteric region. Such cysts may lead to fracture Incomplete surgical



FIG. 225. Chronic sub-periosteal abscess, with small reaction.



FIG. 226. A Radiograph showing a simple cyst in the neck of the femur of a woman aged 28 years. She gave an incoherent history of trauma and began to have continuous pain in May 1931 which was thought to be due to a femoral hernia. Radical operation for the hernia was undertaken in August 1931. This did not relieve the pain and this radiograph, taken 21/10/31 shows that the cancellous structure of the femoral neck is completely destroyed. The cyst was opened and scraped and gradual consolidation of the cyst is taking place as shown in B taken 7/6/33.

may show similar changes—this condition should be regarded as a polycystic dysplasia (see Fig. 214).

In the series of cases of disease of the upper third of the femur investigated by *Thompson* there were 40 bone cysts, 30 metastatic tumours (twice as many as in the humerus) 11 sarcomata (one-half of the number seen in the humerus) and a number of exostoses.

A hydatid cyst which produced a multilocular expansion of the upper third of the femur is described by *Hsieh*.

Zdansky has illustrated the radiographic appearance of a tumour having the histological characters of a Plasmocytoma of the femur. The radiographs show a large



FIG. 228. Endothelial myeloma. Note the parallel lines of new periosteal bone and the alteration in the cancellous trabeculae. Boy aged 18. Contrast appearance with Figs. 220 and 117A.



FIG. 229. Septic arthritis and osteomyelitis of the upper third of the femur in a woman aged 30 showing rarefaction and erosion of the superior surface of the head of the femur and marked irregular rarefaction with periosteal thickening of the upper third of the femoral shaft.

area of rarefaction at the junction of the middle and upper thirds of the femur which is slightly expanded and has a very coarse trabeculation, and all the compact bone absorbed. Some isolated metastases from carcinoma of the uterus produce similar radiographic appearances.

Endothelioma of Bone. The shaft of the femur is one of the sites of election for the development of endothelial myeloma—the so-called Ewing's Tumour.



Fig. 227B. 6,3'33. After resection of cyst and insertion of fibula as graft.

Fig. 227C 10'9 42. Consolidation and growth of incorporated graft

Fig. 227 Multilocular cyst of the femoral shaft, which redeveloped after what appeared to be complete curetting. The whole section of the affected shaft was later resected and the gap bridged by a length of the fibula. This led to sound consolidation. 6 years after the graft had the build of the femoral shaft (Mr Hendry's Case.)

excavation may be followed by redevelopment: this occurred in the case illustrated in Figs. 227 A and B. The whole cystic area was resected and a bone graft inserted—the latter fractured, but later was progressively built up into the form and stability of the normal femoral shaft (see Fig 227 C). *I. T. Indreason* has published a series of radiographs of a similar cyst which gradually disappeared without any surgery in four years. During this time the patient had U.V. radiation, calcium and parathyroid medication but the details of the treatment are not given. The cystic lesions in hyperparathyroidism show progressive consolidation of the walls and septa following removal of the parathyroid tumour (see Figs. 174 A and B).

Multilocular cystic lesions of this type may be seen at both ends of the femur or localised to one segment of the periphery near the diaphyseal extremity. Several bones

the later stages a thin line of periosteal new bone may be seen or perhaps some calcification in the soft tissues.

Osteogenic sarcomata of the shaft of the femur may present one of the radiographic appearances described in pp. 683–8, Figs. 483 and 486 but owing to the increased thickness of the part the contrast and finer detail are not so clear

The conflicting evidence obtained by clinical, histological and radiographic examination in some of these cases is discussed in the chapter on Bone Tumours.

Metastatic Carcinoma. Metastases from carcinoma of the prostate thyroid, breast supra renals, kidney uterus, stomach, lungs and other organs, very frequently occur in the upper third of the femur

In some cases there is a long latent period between the onset of clinical signs and the development of radiographic evidence of secondary carcinoma, but the radiographic demonstration of these metastases may be the first indication of the presence of any malignant tumour in the patient. It is not uncommon for the radiologist to discover areas of bone destruction indicating such metastases when carrying out X ray investigations for the demonstration of arthritic changes in patients complaining of "sciatica (see Figs. 230 A and B). Other cases are revealed on X ray examination for fractures (see Fig 231).

The primary carcinoma may not be found until several months have elapsed since the bone metastasis was discovered by the radiologist, or may not even be discovered until a post-mortem examination is made This fact may give rise to the opinion that the bone lesion shown is the primary tumour A further radiographic examination of the lumbar spine and pelvis often reveals further lesions.

For the radiographic appearances of secondary carcinoma of bones, see pp. 834–6.

Of the 88 cases showing bone metastases which were investigated by *Joll*, 14 7 per cent showed metastases in the femur



FIG. 231. Radiograph of the left hip joint and upper half of the femur of a woman aged 50 showing disintegration of the upper third of the femoral shaft the sit of a spontaneous fracture —and increased density of the head, neck and great trochanter Carcinoma metastases from the breast The lesser trochanter has been torn away from the shaft of the femur

Sciatica. There is probably no problem in clinical medicine which has been the cause of so much controversy as sciatica. It is a problem with many facets, each guarded by a speciality apparently having its limited confines, beyond which its disciples do not see light contributed from other sources. Consequently they have no hesitation in claiming the lesion in their sphere to be the commonest cause The latter has shown an element of fashion or obsession Thus a few years ago the inciting cause was attributed to dental sepsis, and those who had had their successes following the extraction of septic teeth, have ordered the extraction of the whole of a patient s teeth though experienced dental surgeons and radiologists had found no clinical or radiological evidence of dental sepsis.

The resemblance to some syphilitic lesions is sometimes close (compare Figs. 228 and 117 A).

All types of bone tumours, including chronic inflammatory processes presenting widely different radiographic appearances and clinical manifestations, are being grouped under the heading of Ewing's tumour so that a study of the radiographs of published cases leads only to confusion. The radiographic features of this tumour are illustrated in Fig 228 It should be compared with Fig 229 which is a radiograph of osteomyelitis of the femur The radiographic features of this tumour are described in the chapter on *Bone Tumours in Part II*

Localised Paget's disease has been mistaken for this tumour The age and further radiographs will usually assist differentiation

Sarcoma. The shaft of the femur is one of the more frequent sites for the develop-



Fig. 230A. Radiograph of the pelvis of a woman aged 30 showing indefinite area of rarefaction in the neck and intertrochanteric area of the left femur (1/9/30). Patient complained of pain down the back of the thigh.



Fig 230B. Radiograph of the left hip-joint of the same patient as Fig 230A (16/9/31), showing a pathological fracture of the upper end of the femoral shaft and marked erosion of the bone Primary focus not discovered She had a goitre which was thought to be simple for 20 years. After her fracture she had an acute attack of hyperthyroidism. Subsequently she had fracture of the opposite hip and died There was no increase in the size of the goitre with these bone changes.

ment of periosteal fibrosarcomata and osteogenic sarcomata. Radiographs of the femur in cases of periosteal fibrosarcomata may fail to show any change in the bone There may be a suggestion of uniform hypertrophy of the compact cortex of the shaft This feature in association with a marked tumour is in itself of diagnostic significance In

CHAPTER XI

THE HIP JOINT AND PELVIS

Technique. Much of the value of this scrutiny of radiographs of the hip joint area would have been lost but for the fact that a standard position has been adopted for the majority of the films. To obtain this standard position the patient lies flat on the back with the toes inverted equally as far as possible on both sides and the X ray tube is centred in the mid line vertically over a point midway between the plane of the anterior



Fig. 232A. Radiograph of the pelvis of a boy (8 years) taken with the feet internally rotated. It shows the angle between the neck and the femoral shaft and an almost horizontal epiphyseal line; also that the superior border of the femoral neck forms a segment of a curve which is continuous after the break of the hip joint, with the lateral border of the ilium while the lower border of the neck holds a similar relationship with the inferior border of the pubic bone. The innermost point of the proximal end of the diaphysis and the highest point of the epiphysis of the head are equidistant from the rim of the acetabulum. The epiphysis of the great trochanter is just beginning to ossify.



Fig. 232B. Radiograph of the same boy as Fig. 232A, with external rotation of the feet, showing that in this position the angle of the femoral neck with the shaft cannot be determined. The relation of the bony curves described above is preserved. This is the best position to show lesions of the lesser trochanter.

superior iliac spines and the greater trochanters. This position shows to the best advantage the neck of the femur on both sides and its relation to the head and shaft of the femur. With external rotation of the foot the neck of the femur is brought into the line of the shaft and it becomes difficult to estimate its position relative to the head and shaft; further, the greater trochanter may mask abnormalities of the neck (see Figs. 232 A and B).

Many fractures of the neck of the femur have been missed by neglect of this procedure. Further, unequal rotation of the feet may result in faulty interpretation of the radiograph; particularly is this so in children under 1 year of age if the head of the femur cannot be seen.

With small children, flash exposures without the Potter Bucky Diaphragm are advisable. These give a sharp image as the child does not move and the film is nearer

Contributing to the difficulty in solving the problem is the loose use of the term—it may be applied to any pain or discomfort which is experienced by the patient from the lower back to the heel, unilateral or bilateral in its distribution. Whether the pain is continuous or intermittent, and whatever its character or severity or variation, accompanied or not by muscle spasm, rigidity, altered posture or gait, with or without localised tenderness. Some authorities apply the term only to pains in the path or distribution of the nerve. Some have tried to classify types. The nature of the lesion causing the pain has also been a subject of controversy. By some it is regarded as a fibrositis, by others a peri-neuritis, an interstitial neuritis, cicatrisation of the nerve, herniation of fat, a sacro-iliac strain, a lumbo-sacral arthritis, an arthritis of the lumbar facets, or a prolapsed disc. The inciting cause of the lesion has been attributed to trauma, exposure to cold, draughts or damp, a gouty diathesis, a sensitivity to certain foods, septic foci in teeth, sinuses, gall bladder, respiratory or gastro-intestinal tract. But apart from these nervous and skeletal causes other specialists have attributed the symptoms to disorders and diseases of the gastro-intestinal, genito-urinary or vascular systems. In addition there are physicians who attribute the majority of the symptoms to hysteria and who go as far as to advise no radiology of the area lest it unduly focuses the attention of the patient to the site. The radiologist, on the other hand, finds in his museum so many examples of developmental, traumatic and diseased conditions of the skeletal system that he is apt to think every case will show radiographic evidence of the cause. Actually but a small proportion do this at the first examination; those due to inflammatory changes or secondary carcinoma or sarcoma of soft tissues may not show evidence for several months. In the search for the cause a localised lesion in the bone or joint beneath the tender area should not be forgotten. I have found such lesions when the clinician appeared to have been obsessed with the idea of some more central lesion, and extensive investigation, even involving drastic surgery, have previously been performed without success. In attributing the cause to some unchanging anatomical feature it should be remembered that sciatica is of a temporary character and that certain authorities hold that severe sciatica never occurs twice in the same limb. To-day protrusions from the intervertebral discs are perhaps the most popular explanation given for the cause.

Lesions which may be discovered in the skeletal system by radiography are described in the chapters dealing with the hip joint, pelvis, lower spine and intervertebral discs.

of the grosser type are not common Bilateral congenital absence of femoral shafts with articulation of superior and inferior epiphyses has been recorded (see p 217). Examples are seen from time to time which usually show absence of the normal femoral head and neck and trochanters ; in other words, the upper end of the femur is devoid of its normal characters.

Four examples of this are illustrated by *Leitch*

These cases represent delay only in ossification of the upper third of the femoral shaft, for if radiographs are taken at intervals during the early years of life it can be shown that the upper part with the trochanters and the neck ossify and assume their normal position relative to the epiphysis of the head of the femur which ossifies at its normal time.

A series of such radiographs was obtained of a boy who soon after birth was noticed to have a short right leg A radiograph showed ossification only in the lower two-thirds of the femur and no sign of any bone in the proximal third The nucleus for the epiphysis of the head of the femur appeared at the end of the first year of life and 4 years later a radiograph showed complete ossification of the proximal third in its normal position but with some bowing of this segment and shortening of the limb The radiograph also showed transverse lines of ossification at the lower end of the diaphysis parallel to the extremity and it is interesting to note that these lines are at greater intervals than similar but fainter lines on the opposite femur suggesting that growth from the lower extremity had been greater in the shorter limb during the preceding 1 or 2 years. The short femur was elongated successfully by a step osteotomy

Fairbank[1] described as an unusual case of congenital coxa vara, a case presenting somewhat similar radiographic appearances. The condition was thought to be due to a birth fracture but the radiograph shows ossification in only the lower two-thirds of the shaft. The child died, and at post mortem " it was found that the neck of the femur (apparently absent in the radiograph) was in fact present though cartilaginous.

Kaidare has published details of a case which showed absence of the femoral diaphysis in both sides—the superior and inferior epiphyses articulated (see p 217).

These are not examples of the condition usually called congenital coxa vara in which there is disorganisation of the juxta-epiphyseal region of the neck of the femur a condition which is described later In some cases the femur may be absent, the upper ends of the tibia and fibula articulating with the acetabulum.

Os Acetabuli The acetabulum, though essentially derived from the ilium, ischium and pubis, is formed by the union of a number of intercalated ossicles which appear about the twelfth year in the Y-shaped cartilage between the three main elements. *Quain* states " The largest of these is the os acetabuli it gives rise to the whole of the pubic part of the acetabulum and becomes united about puberty first with the pubic, and later with the iliac and ischial elements another ossicle formed between the latter has, according to *V D Broek* the same morphological status as the larger os acetabuli. His researches seem to indicate that a single or primitive acetabular bone is divided into two portions an anterior between os pubis and os ilium and a posterior between os ischii and os ilium that these may be further subdivided and represented by small nodules. *Denyer* (*Jour Anat*., v 38) described a specimen in which the upper part of the brim of the acetabulum below and lateral to the anterior inferior spine was formed by an ossicle occupying a depression or notch in the bone The author states that from its position the ossicle had no connection with the development of the acetabulum This site in the newly born infant is cartilage

The os acetabuli referred to by *Quain* is not the ossicle to which radiologists give the name os acetabuli (os cotyloideum, os coxae quartum, acetabular bone)

the joint It is advisable in all cases, particularly in children to radiograph both hips on the one plate as by this means a comparative study of the outline density and structure of the bones and joints can be made.

Normal Appearances. The centre of ossification of the head of the femur is said not to appear on the radiograph until about the tenth month of life In some cases, however the ossified nucleus can be seen as early as the second month In normal hip joints these centres are about the same shape and size on both sides, and in 3 or 4 years have assumed a hemispherical shape with a regular epiphyseal line which runs obliquely downwards latero-medially Towards adolescence the epiphysis for the head of the femur becomes concave on its metaphyseal surface and its margins are thinned out to spread over the terminal extremity of the neck. The neck of the femur has a relatively constant angle with the shaft which is about 125 being rather more in children, and less in females, who have a wider pelvis. Centres of ossification for the great trochanter appear about the third to the ninth year while that for the lesser trochanter appears about the eighth to tenth year

The union of the head to the neck, the trochanters to the shaft, and the elements of the acetabulum, takes place from the seventeenth to the twentieth year At this time the contour of the head is about two-thirds of a sphere its regularity being more obvious in young people and females.

Just below and behind the mid point of the rounded articular surface is a small ovoid depression the fovea capitis femoris, which gives attachment to the ligamentum teres. Its radiographic appearance should not be interpreted as a small localised area of erosion

The outline of the acetabulum in the first few years of life, and after 18 years, is relatively regular but, between these ages, it often takes on an irregular crenated outline This appearance is quite normal and should not be interpreted as pathological erosion. The outline of the joint space, *i.e.*, the space between the head of the femur and the acetabulum, should be regular and in its upper third even in width but widening as it approaches the central and deeper part of the acetabulum Any other irregularity or variation in width should be viewed with suspicion. The joint spaces on both sides should be compared—the only indication of arthritis in the early stages may be a relative increase in the joint space on one side

The periphery of the normal femoral neck and the pelvic bones produce two regular curvatures the appreciation of which are of considerable value in recognising displacements and plasticity of the bone The first is Shenton's line—the line of the inferior border of the superior ramus of the pubic bone continued in a regular curve into the line of the inferior border of the femoral neck The other is the line which I have indicated as forming the lateral border of the ilium from the anterior superior spine across the hip joint and continued into the superior border of the femoral neck to the great trochanter Any plasticity of the walls of the acetabulum or of the femoral neck produces alteration in the form and regularity of the second line. With localised plasticity of the roof of the acetabulum the line is breached by a lateral pouting of the lateral aspect of the roof of the acetabulum. In protrusio acetabuli the curved line is broken at the joint and the superior border of the femoral neck comes to lie at right angles with the lateral border of the ilium With plasticity of the femoral neck, or any other factor which results in coxa vara, a in rickets, the angle between these elements of the line is still further reduced and the curvature altered.

Good radiographs should show the bone striation and any variation in the bone density should be most carefully observed.

Congenital Abnormalities. Congenital abnormalities of the upper end of the femur

One radiograph shows the pelvis of a girl aged 7 weeks, and another the same patient at 2 years the latter shows an imperfect sloping roof to the acetabulum on the affected side



Fig. 234A. Radiograph of the pelvis and hip joints of a boy aged 1 year (3 2/29), showing a congenital subluxation of the left hip joint The epiphysis for the left femur has not appeared, while that for the right femoral head is irregular in its ossification. The right acetabulum is relatively well developed.



Fig. 234B. Radiograph of same boy Fig 234A (10 9 31). It shows that the right femoral head epiphysis is now practically normal but the epiphysis of the left femoral head is fragmented and the femoral neck is shortened and thicker as in Perthes disease A manipulative operation has been done shortly after Fig 234A had been taken.

Calot expresses the opinion that most of the affections and disabilities of the hip joint are due to congenital subluxation—an opinion which is not substantiated by

The latter is seen at the highest and most lateral border of the superior lip of the acetabulum, and is probably the same body referred to by *Denger*. It varies in size and shape. It may appear as a thin strip of bone of crescentic shape about ½ inch long, or as a triangular ossicle with its border rounded and measuring nearly ½ inch. There may be no bony union to the ilium, or it may be united at its upper or lower border.

The existence of this ossicle is not so widely known as it ought to be and consequently it is referred to from time to time as a fracture. Though it frequently is bilateral, unilateral examples are by no means rare (see Fig. 233). Where the radiograph has been taken because of an injury to the region of the hip joint, the presence of this ossicle may lend support to a claim for bone injury. If the radiograph includes the opposite hip and this shows a similar ossicle, little difficulty will be experienced in demonstrating the shadow as a variation of the normal.



Fig. 233. Large os acetabuli simulating fracture of the roof of the acetabulum.

In the case, Fig. 233, the patient had an injury to the lower spine and the radiograph of the pelvis showed this unilateral abnormality which looks not unlike a fracture, particularly as its upper margin is sharp as in a recent fracture. Radiographs taken nearly 2 years later however show practically no change—this sharp border is still present and there is no evidence of callus.

Later in life, with the development of osteoarthritic changes in the hip joint, a small ossicle is frequently seen in the same position. This is also referred to as the os acetabuli, but it is of an entirely different nature—it is an osteophyte and part of the osteoarthritic process. *Hans Kaiser* described bilateral hip joint disease of a mother and daughter in whom this os acetabuli was present.

In a patient aged 53 who had clinical symptoms suggesting early osteoarthritis of both hip joints, radiographs showed an unusual bilateral massive development of bone in the lateral aspect of the roof of the acetabulum. This had the effect of deepening the acetabulum. The new bone showed changes suggesting some degeneration and its articular borders were a little irregular—otherwise the joint space was preserved and regular and there was no evidence of reaction in the subarticular bone.

Congenital Subluxation. This condition is recognised before the head of the femur is ossified by the break in the curved outlines of the femur and pelvis, as described in Figs. 232, A and B, by the relative increase in the joint space on the affected side, and often, by the shelving margin of the roof of the acetabulum—these appearances are shown in Figs. 234 A and B.

An excellent example is illustrated with radiographs by *Fairbank* in the *Proceedings of the Royal Society of Medicine, Section of Orthopædics*, June 1925, p. 7. He calls it "a case of unilateral imperfect formation of the hip-joint—subluxation with spontaneous recovery."

epiphysis and the bony acetabulum altered In the later age periods the features shown and described in Fig 235 A will be seen They were indicated by *Putti*

C H Jaeger shows excellent results in two children in whom the condition was diagnosed at 8½ months and treated by applying pressure pads over the great trochanter with the limb in marked abduction

Series of radiographs taken at intervals before and after operative treatment show how important is the early recognition of the deformity if the result is to be successful.



FIG. 236 A. Radiograph showing chondritis of the right femoral capital epiphysis in girl aged 8 years. Note the large interosseous space and the expansion of the femoral neck.



FIG 236 B. Radiograph of the same patient 3 years later The epiphysis gradually ossified from multiple nuclei

Various authorities claim from 50 to 90 per cent. of clinical successes, but radiographically the anatomical successes are not nearly so numerous—in fact, they form a relatively small proportion.



FIG 237 Radiograph of the hip joints of a girl aged 6 showing stunted development of the head and neck of the left femur following unsuccessful attempts to reduce a congenital dislocation.

As a result of forcible manipulation damage is caused to the growing bone, and faulty stunted development occurs. In some cases the trauma of manipulation appears to destroy the ossific nucleus for the epiphysis—no ossification may be seen in it for several years and the femoral neck appears to be stunted in growth (see Fig 236 B)

radiographic examinations—congenital subluxations being in my experience less frequent than congenital dislocations.

Congenital Dislocation. In a series of 88 examples of this deformity 15 occurred in males, 73 in females. In the males both the hips were dislocated in 2 cases, the right hip in 7 cases and the left hip in 6 cases. In the females, 23 had both hips dislocated, 17 dislocation of the right hip, 33 dislocation of the left hip. This shows a greater incidence in females, in whom also a higher percentage had both hips dislocated, but in whom dislocation of the left hip was most common. Unilateral congenital dislocation was present in the same side in twins. In 3,500 cases referred to by different authors, 84 per cent. occurred in the female and 16 per cent. in the male. Success in operative treatment depends to a large extent on the earliest recognition of the deformity and



. 235A. Radiograph of a girl aged 1 year owing a congenital dislocation of the left hip int Not that the epiphysis on the dislocated side is smaller than the right; the ormal curves are broken into by the displacement of the femur; the roof of the etabulum does not appear to have developed, and there is alread the suggestion of a lse acetabulum developing abov the normal.



FIG 235B. Radiograph of same patient as Fig 235A, aged 3 years. The acetabulum is now well developed and the dislocation is completely reduced. These radiographs (Figs. 235, A and B) illustrate how well the acetabulum may develop if the dislocation i completely reduced with a minimum of bone trauma.

as the femoral head may not be seen in radiographs of children before the end of the first year of life it is essential that perfect symmetry of the patient and centralisation of the X ray tube be obtained before making the radiograph. The excellent results which can be obtained by early treatment are shown in a case treated by *Naughton Dunn* (see Figs. 235 A and B).

For the recognition of the displacement in the first months of life it must be realised that in the normal hip-joint the bony base of the acetabulum is concave Its lateral border appears to be cut off and has the appearance of a facet about half the size of the concavity which faces more laterally The ossific nucleus for the femoral head lies opposite and its near surface parallel to the bony concavity As indicated by F H Kemp these features are defective in congenital dislocation and the relationships of

Figs 235 A and B. It is said that adults with untreated congenital dislocations suffer much pain from the deformity yet they are rarely sent for radiographic examination



Fig. 239 Radiograph of a girl aged 13 showing a congenital dislocation of the left hip joint Note the femoral head, neck and shaft are not so well developed as the right and that a false acetabulum has been developed in the left ilium

My explanation for this is that the patient has always had more or less discomfort in the hip joint, the secondary arthritic changes with accompanying pain develop gradually and the patient submits quietly to what he believes is inevitable.



Fig 240. Radiograph of the hip joints of a girl aged 11 years, showing coxa valga deformity with subluxation of the left hip joint. Not hypoplasia of femur of paralysed limb. A case of infantile paralysis.

Radiographs of the untreated congenital dislocation show that in some cases the head of the femur articulates with the body of the ilium and a false acetabulum may be formed, as in Fig 239 The ilium does not always show the development of a false

Appearances of the head of the femur after manipulation similar to those seen in osteochondritis deformans juvenilis coxæ (Perthes or Legg s Disease) are not infrequently seen and may be interpreted as osteochondritis unless the history is known. Later if the head remains in the acetabulum, there is frequently premature fusion of the epiphysis with the neck, and the condition of coxa vara develops

If a radiographic and clinical examination of all the cases of congenital dislocation of the hip, in which attempts had been made to reduce the deformity several years previously were undertaken it would indicate that, except in the hands of the skilled



FIG. 239. Radiograph of the hip-joints of a girl aged 13 years, showing bilateral stunted development of the femoral heads and necks, though the bilateral dislocations had been completely reduced.

orthopædic surgeon, end results are very far indeed from the success expected shortly after the operation was performed (see Figs. 237 and 238)

A series of cases showing injuries to the growing epiphysis by operative procedures illustrated with radiographs has been recorded by *Freund*

Even though the dislocation is reduced in infancy and the femoral head kept opposed to the acetabulum throughout adult life, the acetabulum may retain its sloping roof and remain very shallow while the femoral head as the result of trauma and the subsequent osteochondritis may be considerably mushroomed and expanded. Marked bilateral coxa vara has been seen in adults in association with the above features.

Choyce analysed 50 published cases and showed that deformity as in osteochondritis, resulted in some of the cases in which the history had been followed up. He comments on the fact that this is not usually done Even after the most careful reduction it is impossible to say that the result will be anatomically perfect, because the dislocation is often associated with a very imperfectly developed acetabulum which fails to hold the head in its true anatomical position during its later development with weight bearing The radiographic appearance following operative procedures emphasises the importance of reducing trauma of the displaced head of the femur to the minimum. That the deformity can be reduced and normal development proceed afterwards is shown by

Figs. 233 A and B. It is said that adults with untreated congenital dislocations suffer much pain from the deformity yet they are rarely sent for radiographic examination



FIG 239 Radiograph of a girl aged 15, showing a congenital dislocation of the left hip joint Note the femoral head, neck and shaft are not so well developed as the right and that a false acetabulum has been developed in the left ilium.

My explanation for this is that the patient has always had more or less discomfort in the hip joint, the secondary arthritic changes with accompanying pain develop gradually and the patient submits quietly to what he believes is inevitable.



FIG. 240. Radiograph of the hip joints of a girl aged 11 years, showing coxa valga deformity with subluxation of the left hip joint. Note hypoplasia of femur of paralysed limb. A case of infantile paralysis.

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FIG. 238. Radiograph of the hip-joints of a girl aged 18 years, showing bilateral stunted development of the femoral head and necks, though the bilateral dislocations had been completely reduced.

orthopædic surgeon end results are very far indeed from the success expected shortly after the operation was performed (see Figs. 237 and 238).

A series of cases showing injuries to the growing epiphysis by operative procedures illustrated with radiographs has been recorded by *Freund*

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rare accident. He described a specimen in the Museum of the Middlesex Hospital, showing this fracture, and stated that he believed such specimens were rare and that only about five such specimens would be found in the museums of this country.

The incidence of this fracture cannot be ascertained from the number of specimens in museums, as one would expect it to be a very rare occurrence for such an accident to result in a post mortem examination. Radiographic examinations reveal that this fracture is more common in children than might be supposed from clinical examinations, and unless a radiograph is taken the diagnosis may not be made even when the lesion is present.

In the cases of fracture of the neck of the femur in children which have been seen in this series, the children were sent for X ray examination because they had suffered an injury in the region of the hip-joint not because the clinical signs of fracture of the neck of the femur had been detected. A careful clinical examination may fail to detect in children the signs of fracture seen in the adult, and if a radiograph is not taken, the patient may be allowed to walk about after the acute pain of the injury has subsided. Later owing to the development of a coxa vara deformity with limitation of movements, the true nature of the injury may be suspected and shown on a radiograph. Incomplete fractures of the femoral neck the so-called Fatigue or March Fractures, may be first detected by radiographic examination.

Telford has referred to this latency of symptoms, and *Lindsay* has described a fracture of the neck of the femur in a girl of 12 in whom there was good bone union in a coxa vara position within 6 months. This patient began to limp in May but the fracture was not discovered until June.

Radiographs show that the fracture is most commonly through the middle, but sometimes through the base of the femoral neck.

Taylor states that he has had 7 cases of fracture at the base of the neck in children under 18 years of age.

The epiphyseal line is spared, and I have not seen any case of severe trauma referred for an X-ray examination to ascertain the possibility or extent of a bone injury in which the radiograph has revealed a simple separation of the epiphysis. This is in accord with all traumatic separations of the epiphysis in other bones, the radiographs of which all show that a fragment of the diaphysis is carried along with the displaced epiphysis. This has been well illustrated by *Thurstan Holland*.[1]

The possibility that trauma may produce only degenerative changes in the metaphysis which permits the epiphysis to slip off the end of the neck under the shearing strain to which it is normally subjected, is the theory of a number of authorities (see chapter on "Slipped Epiphysis").

Elmslie considered that in children under 5 or 6 years of age, a fracture generally takes place, whereas, in children over this age a separation of the epiphysis occurs.

As a general rule, most of these fractures in children result in bony union in a coxa vara position. Occasionally even in children, the fragments fail to unite. *Perkins* has described an ununited fracture of the neck of the femur in a girl 18 years of age, the fracture being through the middle of the femoral neck.

In my series a radiograph of a rare condition, a fracture of the neck of the femur on both sides, due to a fall, in a girl 16 years of age was seen. Further radiographs showed good bony union within 6 months with a bilateral coxa vara deformity.

Radiographs of children during the "active" stage of infantile coxa vara show a fragmentation of the middle third of the neck of the femur which is reported on from time to time as a fracture.

Fracture of the neck of the femur in adults is frequently met with. It often follows

acetabulum. Considerable hypoplasia of the dislocated heads may be seen in some adults with almost complete decalcification of large circumscribed areas of the ilii surrounding the femoral heads.

Such joints are mechanically unsound and cannot stand up to the stresses and strains of normal function and therefore like all defective joints, develop osteoarthritic changes early

Variations in the Angle of the Neck of the Femur with its Shaft. The normal angle of the femoral neck with the shaft is 125 It is somewhat greater in children and less in females owing to their wider pelvis. Diminution of this angle produces the condition known as Coxa Vara, whereas increase of the angle is known as Coxa Valga. The latter condition coxa valga, is relatively rare compared with the frequency of coxa vara It is most often seen in cases of paralysis or disuse of the lower extremities, that is, when there is no muscle function, as in congenital deformities with paralysis, hydrocephalus, amputation, infantile paralysis and sometimes in rickets. With coxa valga of marked extent the femoral head is pressed against the lateral aspect of the superior lip of the acetabulum this is pushed upwards, becomes flattened out, and subluxation may occur (see Fig 240).

W Müller[1] *Scheuermann*, and the author[11] have illustrated examples of coxa valga in which the unusual deformity had been produced by slipping of the femoral capital epiphysis, which had become displaced upwards and rotated outward.

Coxa Vara. The causes of coxa vara are many—the chief being —

(1) Trauma.
(2) Localised "osteochondritis of the femoral neck—the so-called congenital or infantile coxa vara.
(3) Slipped epiphysis of the femoral head
(4) General bone diseases :—
  (*a*) Rickets.
  (*b*) Osteomalacia.
  (*c*) Achondroplasia.
  (*d*) Chondro-osteo-dystrophy
  (*e*) Cretinism.
  (*f*) Paget's Disease.
  (*g*) Osteogenesis Imperfecta.
  (*h*) Renal Rickets.
  (*i*) Polycystic Dysplasia.
  (*j*) Polyostotic Fibrous Dysplasia.
(5) Localised bone disease :—
  (*a*) Tuberculosis.
  (*b*) Osteochondritis Deformans Juvenilis Coxae.
  (*c*) Syphilis.
  (*d*) Osteomyelitis.
  (*e*) Simple Cysts.
  (*f*) Malignant Tumour

FRACTURE OF THE NECK OF THE FEMUR

Fracture of the neck of the femur is a relatively common fracture in elderly people. Its frequency in each age period diminishes until below the age of 20, when its incidence again shows an increase. *Sir John Bland Sutton* in his Presidential Address to the Section of Surgery of the Royal Society of Medicine 1918, stated "Simple intracapsular fracture of the neck of the femur in boys and girls I think an extremely



Fig. 242A. Union of fracture of femoral neck not consolidated.



Fig. 242B. Pin has cut through plastic bone which is still partly avascular



Fig. 243. Charcot's joint at the site of a fracture of the femoral neck (see p. 297).



Fig. 244 Radiograph of the hip joint of a woman aged 60 showing an ununited fracture of the neck of the right femur Most of the neck of the femur and much of the calcium in the head has been absorbed. The avascular necrotic head is being substituted

a relatively trifling injury and may be unsuspected for some time if the fragments are impacted. As the foot is usually everted, the neck of the femur may be obscured on the radiograph by the shadow of the great trochanter and without careful scrutiny and confirmation by repeated radiographs, the fracture may be missed.

Of those which do heal, a large proportion unite in a coxa vara position, unless the fragment has been controlled by a plaster spica or internal splinting with a bone peg or nail.

It must be realised that even in young people fracture of the femoral neck is often associated with serious disturbance to the blood supply of the proximal fragment for successful treatment is largely dependent on its recognition and the attention which is paid to it. Union of the fragments may occur at the site of fracture although the



FIG. 241 A. Fracture of neck of femur (27.3.37). Avascular necrosis of head fragment.



FIG. 241 B. Union of fracture 28.4.38 but avascular fragment not completely reconstituted and plastic. Coxa vara deformity. The patient was permitted to walk and 5 months later the coxa vara deformity was more marked—the lesser trochanter being on a plane with the acetabulum.

necrotic fragment is not completely reconstituted and until this has occurred the bone in process of substitution and the adjacent bone is abnormally plastic and will bend or be cut through by the pin if subject to weight bearing. The latter must not be permitted until radiographs indicate that all the avascular bone has been removed, *i.e.*, when there is no more bone in the fragment of a greater density than the adjacent living bone.

These features are well shown in Figs. 241 A and B. Fig. 241 A shows increased density of the head fragment and no definite evidence of bony union. Fig. 241 B, months later shows good union of the fragments but still a marked increase in the density in main trabeculæ of the head fragment. Because of the evidence of union, and because the phenomenon of plasticity was unheeded weight bearing was permitted which resulted in an extreme coxa vara with the great trochanter closely applied to the ilium

If this pre-slipping stage is due to renal rickets, which is but one of the causes I have established in a number of patients, the radiographic appearances may vary considerably in a relatively short time. Thus, in one case under observation the appearances described were present at one time and absent a month later Apparently the bone changes are an index of the gravity of the renal disease at the time



Fig. 243. Radiograph of the pelvis and hip joints of a boy aged 16 (7/4/33). It shows that the epiphysis of the head of the femur on the left side has slipped. Note the well-defined metaphyseal periphery of the epiphysis and the ill-defined margin of the upper end of the diaphysis. The lower margin of the epiphysis is below the level of the lower margin of the acetabulum and on a plane with the superior surface of the lesser trochanter The upper margin of the diaphysis is as high as the highest point of the epiphysis. On the right side note the denser margin of the epiphysis, the woolly margin of the diaphysis and the thickened metaphysis—the pre-slipping stage. Note also similar changes in the borders of the sacroiliac joints. Case of renal rickets. This boy died of uraemia 2 years later

As the slipping may not be appreciated from its appearance on the antero-posterior radiograph in the early stages, it is advisable to take a lateral radiograph of the femoral neck This may in some cases, show a slight displacement better

One writer whose experience must be very limited has recently stated: "There is no such stage. But in support of the claim which the author originally made in 1933, *M B Howorth* states: "The existence of the pre-slipping stage has been denied but there is abundant evidence to support its existence It may not be seen when the child does not seek early medical aid or when this stage is not recognised by the clinician. Nineteen of these cases had definite symptoms, signs and radiographic changes, without evidence of slipping in antero-posterior and lateral roentgenograms and with pathological changes upon exposure of the hip joint at operation. Slipping subsequently occurred in two of them whereas in the others the evidence of disease disappeared after operation."

The Acute Stage. The radiographic appearances of the epiphysis of the head of the femur which has recently slipped are very typical (see Fig 245)

The epiphysis usually has a very clearly defined and regular metaphyseal periphery as if outlined by a pencil, its convex articular border being regular except for the fovea. It is in the form of a cap which appears to have slipped off the upper convex extremity of the neck of the femur the margins of which are now higher than the corresponding margins of the epiphysis, the relative positions being determined by the degree of slipping

Even if a Smith Petersen pin has been inserted and union secured, as indicated by the radiograph, weight bearing must be very cautiously permitted if there is the slightest evidence of avascular necrosis, otherwise the pin will cut through the plastic bone This is well illustrated in Figs. 242 A and B The signs of avascular necrosis and its consequences are discussed on pp. 640–9

Failure of fusion of the fragments in some cases is due to the development of a neurotrophic joint between the fragments as in Fig 243

SLIPPING OF THE EPIPHYSIS OF THE HEAD OF THE FEMUR

The deformity known as adolescent coxa vara is due to displacement of the epiphysis of the head of the femur Really the epiphysis rotates in the acetabulum. It is the diaphysis which is displaced by slipping The deformity usually occurs during the age period 12 to 21 years of age. Of disease and deformities of the hip joint commencing during this period it is perhaps the most common In 287 children under 20 years of age showing disease and deformities of the hip joint this condition was met with by the author [29] in 26 cases. Eighteen of these 26 cases were males and 8 were females. Of the 18 males, in 13 the slipping was on the left side in 4 on the right, and in the other the epiphyses of both femora had slipped

In 1 case though definite slipping had taken place on one side only the metaphysis of the opposite side was widened and its borders were irregular—suggesting a pre-slipping stage.

In the 8 females, the slipping had occurred on the right side in 5 and on the left side in 3

The condition would therefore appear to be more common in the male on the left side.

Radiographic Appearances. The radiographic appearances may be best described by considering the condition in three stages

(1) The pre-slipping stage—before the slightest displacement has taken place

(2) The acute stage—immediately after the epiphysis has slipped.

(3) The chronic stage—the resulting deformities.

The Pre-slipping Stage. That this stage exists as a pathological condition is indicated by the clinical history of most of the patients who complain, often for several months (in one case in the series for 4 years) of dull aching pain in the affected hip joint which is relieved by rest and aggravated by fatigue Owing to the fact that the clinical signs and symptoms sometimes resemble those seen in tuberculosis, radiographs of the affected hip joint may be made These will show no evidence of tuberculosis There will be no local or general rarefaction of the bone no localised erosion, no irregularity of the joint space or articular surfaces, no break in the continuity of the bone lamellæ, but the metaphysis may be thickened in part or throughout the whole of its width. In such cases the metaphyseal periphery of the epiphysis will be well defined, almost as if it had been outlined with a pencil the diaphyseal border on the other hand will be ill defined and woolly in appearance (see Fig 245) These signs are more marked in Renal Rickets. The importance of recognising this stage will be fully appreciated by all who have seen the deformity and disablement which may result from the slipping of the epiphysis and damage to its vascular supply no matter what care and skill has been exercised in reducing or attempting to reduce the deformity

The recognition of this stage will suggest treatment designed to prevent the slipping and any investigation or treatment which will do this should be rigorously pursued In a later paragraph one cause of this condition is given and the treatment of this cause is much more likely to prevent slipping than any form of splint

forced against the inferior surface of the neck of the femur (see Fig 247). There is no irregularity of the bone trabeculae or surfaces to suggest bone disease or injury The joint space and the articular surfaces of the joint appear to be unaltered The convex upper margin of the diaphysis is usually not so clearly defined as the normal its outline appears to be woolly which to some extent explains the radiographic appearances of the so-called pre-slipping stage If the radiograph includes the sacroiliac joints, the outlines of these joints may show the same blurred or woolly appearance as in Figs. 245 and 246.

Other indications of bone pathology are rarely seen in these cases but in one case in the series the slipping of the epiphysis was accompanied by disintegration and softening



FIG. 248A. Radiograph of the left hip of a boy aged 13 (23/1/29) showing slipping of the epiphysis with osteochondritis of the roof of the acetabulum and lateral projection of displaced softened bone.



FIG 248B. Radiograph of the same patient as Fig 248A (18/12/30), showing that the epiphysis has fused to the neck in a coxa vara deformity and the acetabulum has consolidated.

of the roof of the acetabulum, a condition resembling Legg-Perthes disease of the epiphysis. As a result of pressure on the softened plastic acetabular roof this had been "squeezed" out of its normal shape to form a projecting lateral lip Three years later when the acute stage of the disease had passed, radiographs showed that this lateral projection had consolidated the epiphysis of the head of the femur had fused with the neck in a coxa vara position, and the upper end of the great trochanter was higher than the articular surface of the acetabulum (see Figs 248 A and B) This patient had complained of pain in the hip-joint for 0 months prior to the slipping

The Healed or Chronic Stage. No matter how skilfully the epiphysis is reduced to its normal position it will prematurely fuse with the diaphysis, and when this occurs without degenerative changes in the epiphysis the best possible result will be obtained. Consequently the patient is bound to get some degree of shortening of the affected limb

(see Figs 243 and 240) The pressure of the upper end of the neck against the "freed" crescentic epiphysis, the convex surface of which is applied to the articular surface of



Fig. 240 Radiograph of the pelvis and hip joints of the same boy as Fig 243 two months later It shows some increase in the thickness of the right metaphysis

the acetabulum, tends to increase the displacement by forcing the epiphysis to slip in *the acetabulum downwards and backwards with some inward rotation In cases with*



Fig. 247 Radiograph of the right hip joint of a man aged 44 showing an old slipped epiphysis with the lower metaphyseal border of the epiphysis ankylosed to the upper border of the lesser trochanter The superior joint space is obliterated and the opposing surfaces sclerosed, due to chronic arthritic changes.

extreme displacement, the upper end of the diaphysis comes into opposition with the superior border of the acetabulum and the metaphyseal surface of the epiphysis is

Disease. Acute pyogenic infections of the hip joint very commonly destroy the metaphyseal tissue and result in the separation of the epiphysis as a sequestrum (see Fig 250) *Frolich Platt* and others consider that the separation may be brought about by a low grade of sepsis. *Lindemann* has reported and illustrated with radiographs a case occurring in a congenital syphilitic child of 12 years of age suggesting that the metaphysis was disorganised by the syphilitic process.

Localised osteochondritis, disturbances of endocrines as instanced in the adiposogenitalis type of dystrophy have been put forward as the causative factor *Schwartz* stated as his opinion that separation of the normal epiphysis was not possible, and that it was due to some unknown disease of the cartilage



Fig. 250 Radiograph of the pelvis and hip joints of a boy aged 10, showing displacement of the epiphysis of the head of the femur on the right side, due to acute, pyogenic arthritis Changes are also shown in the epiphysis on the left side Both epiphyses show signs of avascular necrosis.

Many observers, notably *Block Fiorani Froesch, Hofmeister Haedke E. Müller* and *Pelleohn*, have suggested rickets as the causative factor though many others have strongly opposed this theory

Key [1] who has published the results of an extensive investigation of the published cases, as well as the findings in a number of cases which he has examined, states "The only abnormality thus far detected is a slight broadening of the cartilage of the epiphyseal line At this period some changes occur in the region of the epiphyseal line which cause a weakening of the structures which bind the head to the neck of the femur The nature of this change is unknown, as no such case has ever been studied pathologically" and later "It is further to be noted that in frankly rachitic children I have never seen a case of separation of any epiphysis, nor have I been able to find a single such case in the literature." A series of radiographs of two patients in my series illustrate that slipping of the epiphysis, though rare in frankly rachitic children, can occur; and the details of the cases of renal rickets supply definite evidence of the nature of the pathological process which leads to slipping of the epiphysis in adolescence in some cases.

The best result I have seen was demonstrated to me by *S T Irwin* His patient had a complete separation of the epiphysis which he replaced, premature fusion with the diaphysis occurred, but in such excellent position that only ½ inch shortening of the limb could finally be detected.

In many cases Avascular Necrosis of the Epiphysis results from the displacement The sequence of changes which results are discussed on pp 610–0

Degenerative changes in the epiphysis of varying severity which seriously deform the hip joint and affect its movements are not infrequent (see Fig 240).

If the nature of the hip condition has not been recognised, or *unsuccessful attempts are made to reduce the deformity the epiphysis is usually forced below the neck of the*



Fig. 240 Radiograph of the pelvis and hip joints of a girl aged 22, showing chronic arthritic changes resulting from incompletely reduced slipped epiphyses. The epiphysis on the left side slipped 10 years earlier during the period when this hip was bearing most of the weight to relieve the opposite side On the left side the acetabulum has been increased in size and deepened to accommodate the deformed head nd neck, giving it the appearance of early protrusio acetabuli. On the right side the epiphysis was displaced to a greater extent. The roof of the acetabulum has been splayed out and is sclerosed to oppose the articular surface found on the upper part of the femoral neck. The expansion of the acetabula is secondary t the plasticity of the bone induced by avascular necrosis of the epiphyses. Note the coarse cancellous bone which is being substituted in the left epiphysis.

femur and its metaphyseal surface comes to lie in apposition to the inferior surface of the neck of the femur to which it may become ankylosed The extremity of the neck will then be applied to the upper border of the acetabulum and a false joint made which, radiographs show develops chronic arthritic changes early as in Fig 247

Ætiology Numerous investigations have been made by different workers to determine the causes of this condition Their opinions can be grouped under three headings: (1) Disease, (2) Static (weight-bearing stresses and strains), (3) Traumatic Personally I am of the opinion that each of these factors comes into operation to some degree in that there is some disorganisation of the metaphysis, which lessens its capacity to withstand the normal shearing stresses and strains, and that because of some trauma which would not have affected the normal femur the condition may be brought into prominence sooner than by the weight-bearing or shearing strain alone Slipped epiphysis has been observed in the children of one or other parent who had previously developed the lesion



FIG. 232A. Radiograph of the pelvis and hip joints of a girl aged 6 years, showing a triradiate deformity of the pelvis and bilateral coxa vara due to rickets. A bilateral subtrochanteric osteotomy was performed.



FIG. 232B. Radiograph of the pelvis and hip joints of the same patient as Fig. 232A taken 14/11/32, 4 years after Fig. 232A. It shows a marked improvement in the shape of the pelvis, but the left femur (on the right side of the figure) shows slipping of the epiphysis of the head of the femur. The remodelling of the shafts at the site of the osteotomies is well shown.

The displacement of the epiphysis in the case illustrated in Fig. 231A is relatively slight and quite different in the radiographic features to the ordinary case of slipped epiphysis due to the fact that this patient is much younger (only 5 years of age) than



Fig. 231A. Radiograph of the hip joint and pelvis of a boy aged 5 years (28/4/32), showing bilateral coxa vara deformity due to frank rickets. Note the irregular metaphyseal borders of the epiphysis, which also show slight displacement due to surgical abduction—more marked on the left side.



Fig. 231B. Radiograph of the same patient as Fig. 231A (14/11/33). Attempts to remedy the deformity were made by putting the patient on an abduction frame fully abducted for 4 months. Radiographs at the end of this time showed that avascular necrosis had resulted from the displacement and the irregularity in density indicates that the necrotic bone is being substituted. The patient had been off the frame for about 8 months when this radiograph was taken. It shows bilateral coxa vara deformity but no displacement of the epiphysis. The metaphyseal borders are now more clearly defined.

those patients in whom slipped epiphysis more commonly occurs (see Figs. 251 A and B). The radiographs of another case (Figs. 232, A and B) show a different state of affairs. In this case the patient showed very marked rachitic deformities of the pelvis and femora at the age of 6, but no slipping of the epiphysis. Later bilateral osteotomy of the upper end of the femoral shafts was performed and the radiographs show clearly the remodelling of the shafts following the operation.

The last radiographs taken 6 years after the operation show that the epiphysis of the left femur has commenced to slip. This suggests that the altered mechanics, due to

his renal disease he cannot stand, consequently the femoral metaphyses are not subjected to the strain of the erect position which the less disabled patient is allowed to endure.

The radiographic evidence of cases of type A renal rickets proves therefore that this condition can induce slipping of the epiphysis of the head of the femur and even of other epiphyses. The rapid disappearance of the active rachitic changes at the metaphysis would account for the objections of many observers who have stated that the bones showed no evidence of rickets. It is illustrated in the second case in which, after an interval of one month marked changes were shown on the radiographs, the metaphysis being then almost indistinguishable from the normal. I have examined the urine of 2 further cases of slipped epiphysis which have united and found much albumen though the bones do not show the changes described. Slipped epiphysis on one side may occur with Legg's disease on the other (see Fig 253)



FIG. 253 Renal rickets Osteochondritis of left femoral capital epiphysis—opposite epiphysis of right has slipped.

Harwell Wilson reported that the metaphyseal tissue in the case of renal rickets was indistinguishable from that in florid rickets, and microscopic examinations of the metaphyseal tissue of the hip joints excised by *Kocher Frangenheim* and *Haedke* revealed alteration in the cartilage and the presence of osteoid tissue

I am convinced therefore that renal rickets can be a definite cause of slipping of the epiphysis of the head of the femur *Lindemann* has shown that slipping of the femoral capital epiphysis may occur as a result of congenital syphilis in which disease the radiographs of the joints show somewhat similar changes in the metaphyseal regions. There may have been an associated disturbance of renal function due to the syphilitic infection. Not in all cases of slipped epiphysis can evidence of renal disease be obtained In some cases this may be due to an improvement in the renal condition at the time the investigation is made In others there may exist excretory or secretory disturbances of other organs which produce this metaphyseal disorganisation. So definite are the metaphyseal changes that they must indicate pathology of the growing bone, and if

the osteotomy acting upon bone during an active rachitic phase, has resulted in a slipping of the epiphysis.

Renal Rickets. The histories of the following cases of type A renal rickets together with the radiographs undoubtedly place this disease as a very definite cause of slipped epiphysis.

In the paper published in the *Lancet*, April 2nd, 1932, I stated that "Slipped epiphysis appears to be due to some disintegration of the metaphysis rather than direct trauma, as most of the patients with this condition give no history of trauma and the radiographic appearances do not support the trauma theory." Since this was written, a patient, a boy of 16, was sent to me for X-ray examination of the hip joints. The radiograph of the hip joints showed that the epiphysis on the one side had slipped and the metaphysis on the other was thickened—the pre-slipping stage.

The history was obtained that 1 year previously the patient had had an osteotomy of the lower end of the femur for the correction of knock knee, so radiographs were made of both knees to see if they would throw any light on the pathology. These showed a *definite thickening of the metaphyseal area of the upper end of the left fibula, but no* such change in the metaphyses of the lower ends of each femur or upper ends of the tibiæ or of the right fibula. From these appearances I suggested the diagnosis of renal rickets which was confirmed later by the characteristic appearances of renal rickets in the epiphyses of the radius and ulna and the finding of a large quantity of albumen in the urine. No suggestion of renal disease had been previously suggested. The patient died of uræmia 2 years later.

More recently another patient was sent for radiography of the knee joints. These radiographs showed that the lower epiphyses of both femora had a slight degree of slipping, while the metaphyses of the upper ends showed the appearance which I have described as the pre-slipping condition. Again, it was suggested that the condition was that of renal rickets, and urine examination revealed much albumen.

Radiographs of the upper and lower ends of the tibiæ, fibulæ, radii and ulnæ, and upper ends of the humeri showed a similar thickening of the metaphyseal area. Radiographs of these same areas, only 1 month afterwards, showed a most remarkable improvement; the metaphyses appeared to be almost normal. The two series of radiographs of this patient suggested that while the condition of the metaphysis might permit of slipping of the epiphysis at one period, at another period shortly afterwards, the epiphysis was stable. It might therefore be possible to prevent slipping in these cases by rest during the acute phase. The radiographs of the long bones in these cases do not show the characteristic appearances seen in the radiographs of frank rickets. There is no suggestion of bowing of the long bones or bending of the neck of the femur; except in the immediate neighbourhood of the metaphyses the bones appear to be normal in density and in the last radiographs of case II little indication of the past, though recent, metaphyseal disturbance is to be detected.

Figs. 245 and 246 prove that it is possible for renal rickets to cause a disintegration of the metaphysis of the upper end of one femur with resulting slipping without there being any further radiographic evidence of renal rickets. In the type B of renal rickets which I have described in an earlier chapter the bones are generally softened and bend with pressure as in osteomalacia, which would appear to spare the epiphysis from separation. A radiograph of the pelvis of a youth aged 21 with renal disease which has resulted in this "woolly" type of rickets shows that the pelvis has become triradiate. On each side the epiphysis of the femoral head shows the sclerosed margin and the thickened metaphysis, but instead of the epiphysis slipping, bilateral coxa vara deformity has resulted from marked bending of the neck of the femur. *Owing to the gravity of*

epiphysis through the decalcified zone of bone on which the dense extremity develops (see Fig 80 D) In the condition known as **Osteochondritis Syphilitica** a similar condition may arise (see Fig 281) The radiographs of a baby 14 months old showed a bilateral coxa vara due to disorganisation of the femoral necks At birth the child was 5 weeks premature and weighed only 4 lb and at 14 months only 11 lb 7 oz.

As a general rule this disorganisation of the ossification of the neck of the femur is the only lesion to be found in the osseous system but it is found occasionally as a bilateral lesion in **Cleido-cranio-dysostosis** and in **Albers-Schönberg's Disease**.

The neck of the femur appears to be foreshortened and its inferior border forms a sharp hook like outline with the medial border of the upper third of the shaft, instead of the normal slow bend, which appears to be continuous with the line of the superior border of the obturator foramen described in the legend of Figs. 23* A and B

The angle of the neck with the shaft may be reduced from the normal obtuse angle of 125 to an acute angle and the great trochanter may be forced higher than the superior border of the acetabulum. The head of the femur always appears to be retained in the acetabulum. The condition may be unilateral or bilateral. One side may recover with little departure from the normal position, while the other develops a marked deformity The condition may be recognised radiographically before the nucleus for the epiphysis can be seen, *i.e.*, during the first year of life by the shape and thickness of the cortex particularly on the medial side of the upper extremity of the diaphysis. Instead of the upper extremity of the diaphysis having an oblique or horizontal metaphyseal surface it is more or less vertical.

The appearances are well illustrated in a paper by *Kreuz*. The first radiograph shows the appearance when the child was 8 months old. The metaphyseal surface of the diaphysis is vertical and the cortex of the upper third of the femoral shaft, particularly on the medial side, is thickened and relatively sclerosed Radiographs taken at the fourteenth month and at 4½ years show the gradual development of the condition. A study of the radiographs taken during the development of the condition in 14 cases reveal that the condition has two phases—an active phase during which the bone of the neck of the femur is disorganised and plastic and yields to the body weight and muscle tension with the production of marked coxa vara deformity if these factors are permitted to operate on the plastic bone and a healing phase during which the femoral neck is regenerated and normal bone is laid down. Healing may occur within 2 years with efficient immobilisation, but it may be considerably delayed by neglect or increased strain on the disorganised bone caused by alteration of alignment by osteotomy of the upper femoral shaft. Complete fusion may not occur until the epiphysis fuses with the diaphysis. The condition runs a course which is very similar to that of osteochondritis in other sites.

It would therefore appear to be logical to avoid the erect position and so relieve the disorganised bone from the weight of the trunk, and relax muscle tension by *splinting* until the active phase has passed and the bones have become consolidated. After this no further deformity can develop.

Deformities which had developed during the active phase might reasonably be expected to be *corrected* if so treated while the bone is plastic. Operative treatment with osteotomy *during this active phase* would appear to be contraindicated It may interfere with the normal consolidation which takes place during the healing phase. Figs. 235 A, B and C suggest this. Treatment should be controlled by the radiographic appearance of the bones. That the condition may be due to heredity is shown by *Jones* and *Lovett* who illustrate a bilateral coxa vara in a child whose mother showed a similar deformity

appearance is due to injury as it is through this area that fractures most frequently occur and, further as they differ from the cases we are describing in that the bone heals



Fig. 234A. Radiographs of the hip joint of a girl aged 16 (31/3/25), showing bilateral infantile coxa vara. On the right side note the triangular fragment; on the left side the sclerosed inner border of the femur which is continued to the upper border of the neck. Note that a small fragment of the neck is united with the epiphysis and that the disorganisation is distal to this.



Fig. 234B. Radiograph of same patient as Fig. 234A (10/10/27), showing complete healing and consolidation.

within the time one would expect a fracture to heal, whereas in congenital coxa vara fusion of the involved elements may not take place until the epiphysis unites.

In one respect it resembles infantile scurvy for in the latter condition it is not unusual to see displacement of the extremity of the diaphysis with the metaphysis and

An unusual type of osteochondritis of the femoral neck is shown in Fig 236 This was produced by an injury sustained 18 months previously Avascular necrosis of the



Fig. 236. Radiograph showing unusual type of osteochondritis. The patient a youth aged 17 years, gave a history of injury by falling from a tree 18 months previously Note the fragmentation of the bones indicating activity after fusion of the epiphyses of the great trochanter The vascularity of the proximal fragment had been seriously disturbed. Five years later the fragment had been substituted by bone of coarse cancellous structure.

head occurred. During the next 3 years it was substituted and sound union with coxa vara deformity resulted

RICKETS

The development of coxa vara in rachitic children is part of the general bending of the softened bones owing to the superincumbent weight of the trunk. The radio-



Fig. 237 Tracings from radiographs showing irregularity of ossification with resultant deformities associated with infantile rickets.

graphic appearance of a rachitic coxa vara is quite distinctive as it is always accompanied by the deformed rachitic pelvis. Generally speaking the appearances on both sides are symmetrical. In the young child the end of the diaphysis is expanded and woolly in appearance while the epiphysis is irregular and ill-defined. If the disease is treated early the bone will undergo repair and the deformity of coxa vara will disappear—the



Fig. 233A. Radiograph of the hip joints of a girl aged 8 (6/9/27). It shows destructive changes in the necks of the femora in the juxta-epiphyseal area. The epiphyses are not involved. No history of trauma. The disorganisation of the femoral necks has permitted the development of bilateral coxa vara.

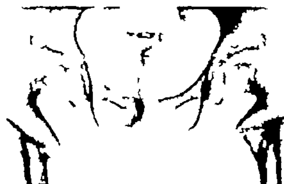


Fig. 233B. Radiograph of same patient as Fig. 233A (6/7/29), showing that there is still some activity in the pathological condition of the neck. Bilateral osteotomy with bone union.



Fig. 233C. Radiograph of same patient (8 12 30) showing absorption of femoral necks. Note the absorption of the shaft in the neighbourhood of the osteotomies. (Compare with Figs. 233, A and B.) The femoral necks were completely absorbed resulting in the appearance of ununited fractures.

It has been suggested that infantile and adolescent coxa vara are due to infantile florid rickets but there is nothing in the radiographic appearance to support this

OTHER CAUSES OF COXA VARA

Osteomalacia (Fig 260) In the adult the bones are rarefied and softened and bend under weight The pelvis is pushed in on both sides the sacrum curves forward,



Fig. 260 Radiograph of the pelvis and hip joints of a girl aged 22, showing marked deformity due to osteomalacia

and the pelvis assumes a triradiate shape while the femoral necks bend, as do the shafts of all the bones of the lower extremities. Quite often one sees marked erosion of the articular surfaces of the hip joints accompanying the general softening and atrophy of the bones. The deformities produced in the adult with osteomalacia are similar to those produced by rickets in the child. In the bones of the pelvis and the upper parts of the femora pseudo-fractures may be shown as transverse lines without calcium bordered on each side by bone containing more calcium than the other portions of the bone Displacement may take place through the site of the decalcified zone (see Fig 320).

Idiopathic Steatorrhœa. In the long-standing case the bones are devoid of compact tissue and the cancellous pattern appears to be coarser than normal. Bending takes place from weight bearing

In **hyperparathyroidism** extreme degrees of osteoporosis with large cystic areas can occur and deformity result from pressure on the soft bone (see p 597).

Paget's Disease. This is another condition where the bones soften, and, as in rickets and osteomalacia, bend with the superincumbent weight. This however does not occur until very late in the disease (see p 600).

Chondro-osteo-dystrophy and Cretinism. In both of these conditions the ossification of the femoral head and neck is often defective and coxa vara develops as a result of pressure on the poorly-ossified bone It will be seen from Fig 264 that the radiographic appearances of the femoral epiphysis in some cases of hypothyroidism simulates that

ultimate deformity depending entirely upon the length of time the condition remains untreated generally and locally (see Figs. 258 and 259).



Fig. 258. Radiograph of the pelvis and hip joints of a boy aged 2½ years, showing the characteristic appearances of active rickets. Note the general "woolliness" of all the bones, the irregular extremities of the diaphyses and the irregular epiphyses.



Fig. 259. Radiograph of the pelvis and hip joints of a boy aged 9 showing a trefoil deformity of the pelvis, bilateral coxa vara, thickened cortex of shafts and coarse reticulation of the bone trabeculae. Untreated healing rickets.

CHAPTER XII

DEFORMITIES OF THE HEAD OF THE FEMUR

THE commonest conditions which produce deformity of the femoral head apart from trauma, are—

(1) Osteochondritis deformans juvenilis coxæ
(2) Hæmophilia
(3) Chondro-osteo-dystrophy
(4) Achondroplasia.
(5) Tuberculosis.
(6) Syphilis
(7) Septic Arthritis.
(8) Cretinism.
(9) Familial Dystrophy

OSTEOCHONDRITIS DEFORMANS JUVENILIS COXÆ

(Pseudocoxalgia, Coxa Plana, Quiet Hip Disease, Legg Waldenström-Calvé Perthes Disease)

The condition was described by *Legg* and *Waldenström* in 1909 *Calvé and Perthes* in 1910, while *Köhler* claims to have published the first radiograph of the condition. *Perthes* found it on both sides in 40 per cent. cases, *Legg* in 12·5 per cent. cases *Krukenberg* in 15 per cent cases.

Incidence. Of the 71 cases of Legg Perthes disease examined by the author in 1934 53 of the patients were boys and 18 were girls. In the boys the right hip-joint was affected in 23 the left hip in 26, and both hips in 4 In the girls, the right hip was affected in 11 and the left hip in 7 This distribution indicates that the disease is much more common in boys than in girls The ages of the patients showing active changes of the disease ranged from 3 years to 15 years. One child, aged 2½ years, showed the typical changes in the femoral epiphysis on the radiograph, but 1 year later a definite septic arthritis of the hip-joint developed. Most of the patients showed the first signs of the disease between the ages of 4 and 8 years.

All the patients in the first instance attended the out patient departments of hospitals, and for the most part appeared to be living in poor circumstances

Theories of its Causation

(1) Traumatic (*Legg*)
(2) Infection or inflammatory (*Froelich McWhorter*).
(3) Congenital stigmata—flattened socket and ischium predispose to coxa plana (*Jansen*).
(4) Unrecognised congenital subluxation (*Calot*).
(5) An osteochondritis as in *Köhler's* disease.
(6) Rickets (*Calvé*).
(7) Rheumatic (*Perthes Brandes*)
(8) Endocrine disorder (changes in the femoral head in cretins).
(9) Embolic (*Axhausen*).
(10) Familial.
(11) Vascular (*Bentzon Zemansky Lippmann Leriche* and *Policard*)

in Perthes disease and chondro-osteo-dystrophy Other appearances are described in Part 2



FIG. 261 Polyostotic fibrous dysplasia. Coxa vara deformity which increased considerably after operative partial evacuation of lesion.

LOCALISED LESION OF BONE DYSPLASIA

Localised Bone Disease Destructive changes in the neck and head of the femur as the result of **Tuberculosis, Perthes Disease Osteomyelitis** and localised **Metaphysitis** may all lead to the development of coxa vara. The history and radiographic appearances are usually distinctive and their characteristic features are dealt with in the following chapter Localised lesions in polycystic dysplasia and in polyostotic fibrous dysplasia also permit of deformity (see Fig 261)

In pituitary gigantism osteoporosis of the skeleton may lead to flattening of the femoral capital epiphyses

Scurvy Displacements of the upper end of the diaphysis through the decalcified zone during the acute phase will result in the development of coxa vara



Fig. 202A. Bilaterial familial coxitis associated with brachydactyly age 14



Fig. 202B. Bilateral familial coxitis associated with brachydactyly age 19



Fig. 202C. Bilateral familial coxitis associated with brachydactyly age 24.



Fig. 202D. Bilateral familial coxitis associated with brachydactyly age 47



Fig. 202E. Bilateral familial coxitis associated with brachydactyly age 83

Congenital and Developmental Abnormalities. The familial distribution of osteochondritis of the hip has been recorded by a number of observers, but the number of such cases does not convince one that this is a factor of paramount importance

Kehl reported a family of 50 members in 6 generations, 20 of whom showed hip joint changes of the *Perthes* type In the family investigated by the author (see Figs 202, A—E), deformity and degenerative changes in the femoral capital epiphyses were distinguishable from Perthes disease

Hans Kaiser reported changes of this nature in the femoral head of the same side in a mother and daughter

Bettman described 19 cases of hip-joint changes in one family but the appearances are not those of typical osteochondritis.

Calot and *Murk Jansen*, who have both devoted much time and labour to the study of these conditions, are keen supporters of the theory that they are primarily due to congenital or developmental abnormalities. Their theories differ somewhat in detail, but the fundamental conception is the same *Calot* explains the varied date of the onset of the symptoms in the following manner He maintains that, although the lesion is congenital, symptoms do not develop until there is a resulting breakdown in function that leads to pain. He therefore regards all cases of *Legg-Waldeström-Calvé-Perthes* disease as not due to disease of the bone but as the result of an unrecognised subluxation that failed to give rise to symptoms until the balance between the suggested subluxation and normal function broke down He regards the bone changes seen in osteochondritis as the *result* not as the *cause* of the deformity

Murk Jansen holds somewhat similar views, *i.e.*, that the cause is to be found in retarded growth of the fœtal envelopes, resulting in imperfect moulding of either or both the acetabulum or the head of the femur He maintains that this results in some slipping of the joint and in injury to the vessels giving rise to fragmentation and flattening of the head of the femur

The author has followed many cases for years, and has watched the development of the condition in joints that were apparently perfectly normal when first examined and in spite of the acknowledged weight of the opinions of such experienced observers, *he cannot agree with the conclusions. His evidence has driven him to the conclusion* that the observed deformities in these cases of osteochondritis are the *result* and not the *cause* of the pathological bone changes. He maintains therefore that they are not congenital

The following points are cited in support of this view

In a series of records of a patient in which both hip-joints are shown, the first radiographs show the typical changes of *Legg-Perthes* disease in the left hip, the right being indistinguishable from a normal hip joint There is no suggestion of flattening of the acetabulum of the right hip-joint, yet 4 years later the early changes of *Legg-Perthes* disease are quite definite. On the left side the bones have consolidated.

In another series of radiographs of a typical case of *Legg-Perthes* disease which, fortunately received early and adequate treatment resulting in the redevelopment of the femoral epiphysis, the healed hip-joint has returned to a condition that is indistinguishable from the normal. Moreover the changes occurring in the acetabulum and in the head of the femur are not necessarily dependent on each other The radiographs of a case of osteochondritis of the roof of the acetabulum showing that this is splayed out over the head of a slipped femoral capital epiphysis are shown in Figs. 218 A and B Other radiographs in the author's series illustrate the progressive development of the acetabular deformities associated with the same sequence of changes observed in osteochondritis of the femoral head and possibly due to the altered stresses occasioned by

not be confused. There is one condition, namely infantile coxa vara, in which serial radiographs show the development and healing of pathological bone changes in the femoral neck somewhat resembling the appearances seen in some phases of osteochondritis. The condition may be unilateral or bilateral. The fact that this condition is frequently seen in cases of cranio-cleido-dysostosis suggests these conditions are due to defective ossification. In the author's opinion there is no connection between the bone dystrophies or dysplasias and the localised osteochondritis that occurs in so many sites.

A bilateral Familial Dystrophy has been investigated by the author in which defective ossification of the femoral capital epiphyses results in marked deformity (see Figs. 263 A and B). The members of the 2 families were very prolific. Radiographs of the



Fig. 263A. Radiograph of hip joints of boy aged 13 years, showing bilateral defective ossification of the femora in the region of the capital epiphysis. Three years later the coxa vara deformity had markedly increased. Compare with Fig. 264B.



Fig. 263B. Radiograph of a brother aged 16 yea[rs] showing a more severe degree of the dystroph[y]. Four years later the beaked femora of cretini[sm] were seen.

younger members showed that some were normal, others showed defective ossification in the region of the fovea which after a few years resulted in plastic moulding of the femoral head and neck and coxa vara deformity. The appearances at some stages resembled those seen in hypothyroidism, and even of the graver deformities, the Beaked Femora of cretinism. In adult life radiographs indicated atrophy of the articular cartilage on the irregular surfaces and the early development of severe restricting osteoarthritis. The degree of deformity varied in the affected members.

In two cases of Progeria recorded the radiographs show unilateral changes resembling Legg Perthes' disease.

Endocrine Disturbances. Hypothyroidism in the young is frequently associated with delay in the ossification and the development of the epiphyses from the fusion of multiple osseous nuclei. Such epiphyses obviously are not homogeneous, and consequently will not respond in a regular manner to stresses and strains placed upon them in this stage, but will be deformed owing to the fact that the well-ossified fragment sustains the weight or strain, while the non-ossified element yields. These deformities and irregularities of the femoral capital epiphyses have also been wrongly labelled as osteochondritis, and observers have consequently suggested that endocrine deficiency is a cause of osteochondritis (see Figs. 263 and 264). Very marked deformities of this nature have been recorded in the hip joints of cretins, as in the case illustrated by

change of shape of the femoral head Osteochondritis of the roof of the acetabulum therefore may be concomitant with, independent of, or follow the development and healing of osteochondritis of the femoral epiphysis.

If the contentions of *Calot* and *Jansen* are correct, one would expect to find osteochondritis as a regular occurrence in cases of untreated unreduced congenital dislocation The author has never seen this, though he has seen many cases of shallow false acetabula in which well-formed femoral heads articulate.

In one brachydactylous family investigated and recorded [44] by the author destructive changes with a severe degree of bilateral coxitis developed from defective flattening of the femoral head which was apparent at the age of 14 The secondary destructive changes are shown to be definite by the age of 10 and with increasing age radiographs showed progressive development of a very destructive arthritis (see Figs. 202 A-F)

Cases of congenital dislocation of the hip which have received surgical treatment not infrequently show changes simulating *Legg-Perthes* disease, but this is a different matter and will be dealt with later The author is therefore convinced that these cases are not congenital in origin, and that the deformity is the result, not the cause of the disease

Bone Dystrophies. In a condition leading to dwarfism, described by the writer as chondro-osteo-dystrophy radiographs of the epiphyses show multiple ossific nuclei and pressure deformities of the epiphyses and ends of the diaphyses. This "fragmentation" has led various observers to regard these changes as evidence of multiple foci of osteochondritis. This condition, however does not show the age periodicity seen in the true osteochondritis the "fragmentation" and deformity become evident with the ossification of each epiphysis, and the fragments do not exhibit the same increased density and subsequent absorption which are important factors in osteochondritis. The lesions in chondro-osteo-dystrophy are bilateral and of equal age, whereas in the bilateral cases of osteochondritis, the stage of the lesion is usually different on the two sides.

The resemblance of the bone changes in chondro-osteo-dystrophy to those of osteochondritis is perhaps nowhere better illustrated than in the paper by *Silfverskiöld* In this paper he has published the radiographs of the hip, knee, shoulder elbow and the joints of the hands and feet of a boy aged 11 years. Any of these radiographs viewed singly might well be misinterpreted as illustrating localised osteochondritis. A case showing similar but not such extreme changes in the epiphyses is also illustrated in a paper by *Martin* and *Roesler* as multiple manifestations of subchondral necrosis. The patient was a girl of 11 years of age when the joint conditions attracted sufficient attention to cause the patient to seek surgical advice. In this case also the individual radiographs bear so strong a resemblance to localised osteochondritis that the authors have considered the lesions to be of the same nature as *Legg-Perthes* disease. The radiograph of the spine is, however typical of a number of cases of c ro-osteo-dystrophy which have been examined by the author who has found ca ll degrees of defective ossification, but having a clinical and radio phic h erent from those of osteochondritis. In one case of cho author's es the radiographs of the skeleton showed th of osteochondritis dissecans of femoral metatarsal heads, changes in all me Fig 272) and irregularity of verteb dystrophy bear a resemblance at ce osteochondritis, a careful cli hi several years, will show tl the pathology the radio-

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of osteochondritis *Legg-Perthes* disease and also rickets are much more common in the poor than the well to-do classes One would therefore not be surprised if a fair proportion of the osteochondritis patients gave a history of rickets. It is also conceivable that insufficient or defective nutrition may be a factor in the causation of osteochondritis *Calvé* has suggested that earlier rachitic conditions deformed the osseous structures in the joint, and produced disturbances of metabolism which led to the inception of osteochondritis. In one of the author s cases a child of six, with bilateral rachitic coxa vara which had consolidated, developed *Legg-Perthes* disease in the left hip (see Fig 252).

In scurvy (*Barlow s* disease) the epiphysis apparently loses its cancellous internal structure and appears on the radiograph as a thin shell of bone. A similar process occurs in the shafts of the long bones but at the growing extremities a metaphyseal zone of densely-calcified cartilage is laid down on a zone very deficient in calcium and tenacity through which the diaphysis may be markedly displaced, yet the writer has not seen a case in which the displacement at this zone has led to changes suggestive of osteochondritis.

In the rachitic changes associated with renal disease, the metaphyseal extremity of the diaphysis is often composed of a thick zone of osteoid tissue deficient in calcium, and with a slight trauma the epiphysis may be displaced opposite hip may show *Legg-Perthes* disease

This change in the diaphysis does not lead to changes simulating *Legg-Perthes* disease. The author has seen a case associated with renal rickets, in which several months after a slipped femoral capital epiphysis had been replaced, the epiphysis showed the changes seen in *Legg-Perthes* disease He does not, however regard the changes of osteochondritis as being due to the renal disorder or to the displacement of the epiphysis (see Fig 253)

Infections. The radiographs and clinical details of some cases might be taken as indicating that changes similar to those of *Legg-Perthes* disease can be produced by staphylococcal infection of the hip-joint. In one case for instance, the early clinical and radiographic findings were indistinguishable from those of typical *Legg-Perthes* disease yet, 1 year later the boy developed a steadv rising temperature, and the clinical signs indicated a definite septic arthritis. A large quantity of pus was aspirated, from which a profuse growth of staphylococci was cultured. The last radiograph of the series taken in this case shows a rarefaction of the femur and its epiphyseal fragments which does not correspond with the typical appearances of *Legg-Perthes* disease.

In the author s series of 71 cases, the above is the only patient presenting these definite signs of inflammatory changes, although a few cases in which infection has been proved have been described by other writers *Kidner* for instance, reported the finding of staphylococci in the curettings from the head of the femur in a case of *Legg-Perthes* disease. Other workers who have conducted bacteriological investigations of the material from cases of osteochondritis, however have not found micro-organisms in such scrapings. The author has had bacteriological examinations made of the cyst like areas which sometimes develop in the juxta epiphyseal region. In no case were organisms detected. Such areas have been erroneously interpreted as Brodie s abscesses.

As already indicated, such clinical and pathological findings are relatively rare and when the whole clinical and radiographic histories of these cases are reviewed, they will be seen to differ markedly from the typical cases of osteochondritis One is therefore bound to consider that either these are cases of osteochondritis with a super added infection in the damaged and unresistant structures, as in Fig 265 or that the inflammatory process has caused vascular disturbances which have led to similar radiographic appearances in the initial stages The author has seen tuberculous arthritis

Berard and *Nové* *Wakeley* has described and illustrated as a case of bilateral pseudocoxalgia a patient, aged 4 years, showing compression and irregular ossification of the epiphyses. He states that the testes of the patient are imperfectly developed, which leads the author to the opinion that the changes in this case are those due to endocrine disturbance and not to *Legg-Perthes* disease. The influence of the endocrine glands on



FIG. 204A. Radiograph of a girl aged 8 years, showing delay in ossification due to hypothyroidism



FIG. 204B. Radiograph of same girl as Fig. 204A aged 10 years, showing bilateral fragmentation of the femoral heads. Patient had been on thyroid medication for over 6 years. Four years later the fragment had consolidated: the appearances then resembled healed Perthes' disease

the development and appearance of the skeleton is not appreciated as fully as it should be, but at present we have no evidence that localised osteochondritis is caused by endocrine dysfunction, though one cannot exclude it as being one of the causal factors.

Faulty Metabolism and Defective Nutrition. Rickets has been suggested as a cause, but though as many as 30 per cent. of the cases may give a history of past rickets, in *none of the 71 cases of Legg-Perthes* disease examined by the author did the radiographs give any evidence of this disease on the other hand, while many cases of neglected rickets have been seen with marked permanent deformities only in one case was there evidence

Perthes disease and in *Freiberg-Köhler's* disease of the second metatarsal, but in sepsis, and even in malignant growths, it is not uncommon to find that the growth cartilage has acted as an efficient barrier. This is well illustrated in the figures in an article by the author (*Brit. Jour. Rad.*, 1934, April).

Incidentally it is rare to see this barrier action in tuberculosis of the bones, though the changes in osteochondritis are of a different nature from those seen in tuberculosis.

The writer has collected a number of cases of hip-joint disease which, on account of their radiographic appearances, had been regarded as simple osteochondritis, though the bone changes bear little resemblance to this condition. He believes that these are cases of syphilis. The pathological changes are usually bilateral, and appear to commence in the epiphysis, which softens and becomes deformed by pressure. Subsequently the articular surface in the region of the fovea appears to be eroded. In some cases the condition responds to anti-syphilitic medication, and the femoral head may show remarkable regeneration. It is possible that other infections may produce similar lesions. Such bilateral lesions were seen in two brothers who had no serological or other evidence of syphilis.

Pneumococcal infection of the hip joint may produce changes in the epiphysis which at one stage may give a radiographic appearance simulating that of osteochondritis.

There are clearly therefore some cases in which definite sepsis can be located that give appearances comparable to, or even at one stage indistinguishable from, those of osteochondritis, but the clinical history, the serial radiographic appearances and the course of the disease in most of them are far different from those which are noted in the ordinary case of osteochondritis.

Aseptic Necrosis. Certain authorities, notably *Axhausen*, explain the changes in osteochondritis as being due to embolic infarction of the affected bone followed by aseptic necrosis. *Axhausen* reports the finding of fragments of bone lying in a disintegrated bone powder within the intact articular and growth cartilage, a condition which he believes is brought about by "impression fractures" of the necrosed bone with subsequent grating of one fragment upon another during the movements of the limb (see General Discussion, pp. 610–19).

Vaso-motor Disturbances. *Bentzon* is opposed to the theory that embolism of the vessels to the particular bone results in aseptic necrosis. He believes that osteochondritis results from a trauma which causes blocking of the periarticular vaso-motor nerves and consequent hyperæmia of the part. Experimentally, by injecting alcohol around these nerves, he claims to have produced changes in the epiphyses resembling those of *Legg-Perthes* disease.

According to the theory of *Leriche* and *Policard* hyperæmia results in rarefaction, and anæmia results in increased density of the bone. *Legg* apparently adopts this theory, for he states: "The hypertrophy of the neck seemed to me to be related to the hyperæmic condition induced, not only temporarily by traumatic congestion but maintained for a considerable length of time by a proportionately increased blood supply, where the blocking of the epiphyseal channels distributed a heavier circulation to the neighbouring diaphyseal vessels." *Möller* also holds this opinion.

The radiographic appearance of the bones in osteochondritis is not readily explained by these theories. The author has shown in the case of *Köhler's* disease of the tarsal scaphoid that it would postulate a hyperæmia of all the bones of the foot except the scaphoid, in which the blood supply would be curtailed, for the scaphoid becomes denser while the surrounding bones become osteoporotic. Moreover, the comparatively increased vascularity of the bones of the affected foot should lead during the first and second years of the affection to a marked disparity of growth of the bones, though we find little or

develop in a joint which had previously shown the typical radiographic series of simple *Legg-Perthes* disease. Cases showing these secondary infectious processes are relatively rare. The question of hæmophilia has been raised, and it has been shown by *Löhr Petersen* and *Montarari* that changes resembling those of *Legg-Perthes* disease may occur at certain stages as the result of hæmorrhage into the joints of hæmophilics.

Some authorities, notably *Freiberg Phemister Platt* and *Knaggs* are of the opinion that the condition is due to a low grade of infection of the affected bone, which causes a non-suppurative, destructive inflammatory process. This opinion is supported by the reports of a few histological examinations which have been made.

These opinions are, however, not supported by the radiographic history of the majority of the cases of osteochondritis, which show a different cycle of changes from those seen in the recognised types of bone sepsis. When bone is attacked by septic processes, osteoporosis is the outstanding radiographic feature, except in those cases where a fragment of the bone dies and separates (as in the case of septic arthritis of the



FIG. 263. Protrusio acetabuli on left which appeared at first as Legg-Perthes disease. Normal course of Legg-Perthes disease on right.

hip joint with separation of the head of the femur). It is only when the patient's tissues have overcome the effects of the sepsis that the living bone begins to fix the calcium salts and assumes relatively normal density. In chronic sepsis, or where a low grade of *infection is present, the bone surrounding the infected area often shows an increased* density. In those cases in which a fragment of the bone dies and separates as a sequestrum, compound fracture for example, the sequestrum retains its density and its sharp outline for many months, and can readily be detected on the radiograph because, while it retains its normal calcium content, the living bone undergoes osteoporosis. When such sequestra are removed they are found to be of the normal hardness of bone and their borders sharp, as if recently broken off. They do not attract calcium, *i.e.*, they are *never denser than normal bone. In osteochondritis it is a different matter* for at first the bone appears to attract calcium and actually becomes denser than normal bone, while the surrounding bones become osteoporotic. Later in the disease the dense bone is completely absorbed, and not until this absorption is complete do we see normal bone structure throughout the epiphysis or the bone involved. Thus in *Legg-Perthes* disease the dense islands of the epiphysis, which have not the sh[illegible] ness of outline of the sequestrum due to sepsis, undergo gradual decalcificatio[illegible] ong as a dense *fragment remains the epiphysis appears to be plastic and und*[illegible] ure deformity. Before final reconstruction of the e[illegible] is, it will be note[illegible] area originally occupied by the last of the dense [illegible] to be absorbed is [illegible] by an area of osteoporosis. Osteochondritis of [illegible] is always asso[illegible] characteristic changes in the adjacent extremit[illegible] iysis. This is [illegible] ses of

changes in the femoral capital epiphysis, which had been displaced and reduced some months previously This is a rare finding In a previous paper (*Brit Jour Surg.*, 1929 No 64) the writer has pointed out that radiographs of the vertebral column taken within a short time of injury may show no bone changes, but that after a few weeks further radiographs may show a deformity of the vertebral bodies owing to the collapse of the damaged cancellous bone.

Summing up the evidence as to the ætiology of osteochondritis, the author is of the opinion that **osteochondritis is the reaction associated with hyperæmia and decalcification which is produced in the living bone by adjacent avascular bone.** It is initiated soon after the fragment has been rendered avascular and persists until all the avascular bone is removed, either surgically or more commonly by so-called "creeping substitution," *i.e.*, by the growing in of vessels from the neighbourhood with absorption of the dead fragment followed by the rebuilding of the bone. What causes the disturbance of the blood supply to the fragment is not clear Bacterial emboli can produce the changes, but, distinct from aseptic osteochondritis, such infarction is in addition associated with the specific reactions of the organism Trauma appears to occur in a large percentage of cases and the possible explanation is that this gives rise to the production of aseptic emboli or neuro-vascular disturbance which temporarily deprive the affected epiphysis or small bone of its blood supply The avascular fragment then induces the osteochondritic reaction in the adjacent bone Different from the septic sequestrum, the aseptic fragment soon shows evidence of commencing revascularisation It is broken up by the invading vessels into small islands. The trabeculæ being broken down in this way the bone is now plastic and can be compressed and deformed by weight or strain. Ultimately the whole of the dead bone is absorbed, and, with the complete substitution by new bone, ossification is completed and stabilisation re-established

DIAGNOSIS AND TREATMENT

Legg-Perthes Disease. *Walter* reporting on the histological characters of the affected tissue, says "The cartilage of the mushroom head is for the most part destroyed and interspersed with bright red granulation tissue and free bone. Connective tissue poor in cells grows from the subchondral marrow which has undergone fibrous change and undermines the necrotic cartilage. Polymorphonuclear cells, eosinophils plasma cells and round cells prove the inflammatory nature of the tissue.

The condition has been the subject of numerous contributions to medical literature, and the student may with advantage read the papers by *Baumgartner Blencke Boyd, Buttner Calot, Calvé Carruthers David, De Raffele Egana, Freund Galvin, Gaugele,*[1] *Harbin and Zollinger Hartley Henson, Kehl Key*[1] *Lange Legg Liesecheid* and *Sellheim McWhorter Miller E. Muller Nussbaum, Platt,*[1] *Perthes Reich Singer Tillier Vignard* and *Wakeley*[4]

Symptoms. A review of the case histories of the writer's patients indicate that the most constant sign of this affection of the hip is *a limp* which may be slight for weeks together and then assumes such an importance that the parents seek medical advice for the child Though a limp could be detected in all the patients, pain in the region of the hip joint was recorded in only 25 of the 71 patients. This showed a great range of severity In some it was appreciated only for a short time on rising in the morning, in others it was present when the patient was standing or walking, in others only after fatigue, but in four cases the pain was so severe during the night that the patient was awakened and cried out. In 11 cases the patient also complained of pain in the region of the knee joint. These signs and symptoms appeared to be so intermittent and varying in severity that a number of the patients had been put to bed from 1 to 4 weeks, with

no difference when we compare them with the bones of the other foot after the lesion has healed.

The writer believes that what is regarded as hypertrophy of the neck of the femur in *Legg-Perthes* disease is nothing more than a compression and shortening of the softened bone.

This is supported by the fact that, in the cases referred to on pp 282-8, the shortening and widening of the neck did not occur when the patient was suitably treated, and the neck was not subjected to the stress of weight-bearing

The upper third of the shaft of the femur sometimes shares in the osteoporosis of the neck and the nutrient foramen appears to be more patent, and the advocates of the theory of *Leriche* and *Policard* would suggest that this is due to a relative hyperaemia owing to disuse. Nevertheless the femoral shaft does not show greater dimensions than the opposite normal side indeed with the diminution of function it is frequently of smaller development than the normal The writer would refer again to the serial radiographic findings in typical cases of osteochondritis, which show that in the early stage the affected bone is denser and the other bones lighter than normal, owing to a readjustment of the calcium content, but that at a later stage, as the condition heals, the calcium fixation swings in the opposite direction until equilibrium is established. This suggests that some process was initiated in the affected bone which caused it to draw upon the calcium in the neighbourhood. That calcium can be stored in the neighbourhood of a joint and be ultimately used there to build up bone, has been shown by the author in a series of radiographs, which show a neurotrophic shoulder joint in which the head of the humerus has been gradually worn away the displaced calcium from the destroyed bone being stored in an amorphous condition within the joint. The radiograph, taken seven months later shows that the amorphous collection of calcium has gone, but a much enlarged bony glenoid has been built up.

Trauma. The most frequent factor associated with localised rarefying changes in the bones is trauma

A history of injury is to be obtained in about half the cases of *Legg-Perthes* disease, and is still more frequent in *Freiberg-Köhler's* disease of the second metatarsal, *Preiser's* carpal scaphoid, *Kienböck's* semilunar *Osgood-Schlatter's* disease of the tibial tubercle, and in most of the unusual sites. It is not, however so frequently obtained in *Köhler's* disease of the tarsal scaphoid.

The earliest radiographic evidence of *Legg-Perthes* disease which the writer has been able to obtain is :—

(1) *An increase in the density of the femoral capital epiphysis* usually associated with

(2) *A relative increase in the joint space* the comparison being made with that of the opposite hip joint, which should always be included in the radiograph. This appearance is soon followed by



FIG. 206A. Radiograph of the hip joints of a girl aged 6 (17/2/28), showing condensation of the head of the right femur and increase of the joint space. No definite changes on the left side. Osteochondritis deformans juvenilis coxæ.



FIG. 206B. Radiograph of same patient as Fig. 206A (18/7/30), showing right-sided coxa vara resembling infantile coxa vara. Reorganisation of the epiphysis. Note the zone of striæ in the right femoral neck passing from the highest point of the femoral head to blend with the medial border of the femoral shaft. This is the zone which is generally involved in infantile coxa vara.

(3) *Osteoporosis of the adjacent extremity of the diaphysis* (Signs (1), (2) & (3) are shown in Fig. 206 A). This osteoporosis may appear as

(a) Linear zones of radiotranslucency following the lines of the principal bone trabeculæ which appear to run obliquely downward and outward from the epiphyseal line.

(b) A zone of radiotranslucency of almost uniform depth across the proximal extremity of the diaphysis (see Fig. 207).

(c) One or more circumscribed areas of radiotranslucency which *may* suggest a focal abscess or cyst in the diaphysis near to or abutting on the epiphyseal

the diagnosis of rheumatism, and then, because all movements of the limb were full and painless, the patient had been allowed the usual freedom, which was invariably followed by similar bouts of disability until eventually surgical advice was sought. In no less than 26 was there a definite history of a fall preceding the onset of the symptoms.

Examination of the Patient. On examination of the patient it will be found that the affected limb shows a degree of adduction and a somewhat prominent great trochanter. A flexion deformity of 10°–15° may be present, and if there is a long history of a limp or pain, the muscles of the limb will be underdeveloped compared with the sound side, giving a suggestion of apparent wasting, though this will not be of the degree seen in tuberculous arthritis. In some cases as much as half an inch of shortening of the affected limb may be detected, but in the majority of this series no such deformity could be detected. The movements of the limb are usually free and painless even though there may be some spasm of the adductor group of muscles. Except in abduction and rotation, which are restricted, the movements are full, and as a rule no tender spot can be elicited.

Radiographic Appearances. In no condition is radiography more helpful than in these cases of localised rarefaction of the bones. The clinical appearance can be very misleading, and for that matter so can the radiographic, unless the bone changes to be seen in the different stages of the condition are appreciated by the observer. The striking feature of the clinical and radiographic findings are that, in the early stages of the disease, the clinical signs and symptoms are usually so prominent for a short time that the negative radiographic appearance may be surprising; or the radiograph may reveal such slight changes that they are not recognised.

An interval of several weeks or months may elapse, during which time the child has been allowed to play about, before the patient is again brought for further surgical inspection.

The clinical signs and symptoms may now be so much improved that they convince the medical attendant that the lesion, whatever it was, is clearing up, but when a radiograph is taken, the appearances cause him alarm. The result of the clinical examination in the first instance, coupled with the rapid improvement of the signs and symptoms, is apparently the reason why many of these patients are not brought for surgical advice until they develop a definite and constant limp. In the author's series the clinical history and radiographic appearance suggested that, in the majority of cases, the hip joint had been affected for one or two years before surgical advice was sought.

It is rare, therefore, that one can obtain a series of radiographs in which the commencement of the affection is shown. Periodic radiographic examination will reveal the stage of the lesion, and give an indication when the bone can safely be subjected to the normal stresses and strains. The radiographic histories of patients of the author's have been analysed.[18 and 22] They show that, on the average, the bone remains in a plastic state for over 3 years, the shortest time observed being about 2½ years, the longest time observed being 10 years, but in this case the patient went through the whole course of the disease in one hip, this lasting 4 years, when the disease commenced in the opposite hip, which has not yet completely consolidated owing to a low-grade infective process in this hip only. Another series of radiographs revealed that, after nearly 4 years, similar changes began to develop in the roof of the acetabulum of the affected hip joint. It will be apparent, therefore, that the radiographs supply valuable evidence, not only for the diagnosis and the study of the pathology, but also for the control of treatment. In a previous paper[22] the author drew up the following time-table of events.

The signs (9), (10) and (11) are shown on radiographs taken during the period of 1½–4 years after the onset of symptoms, and while they are present the epiphysis remains in a plastic state, consequently it may be deformed by pressure. Owing to the deformity of the femoral head the joint space is now irregular but not diminished. Usually during this period the patient has few or no symptoms of hip-joint disease and is allowed to run about without any support or at most, with the support of a caliper only. It is not surprising therefore, that many of these affected femora become permanently deformed for the plastic epiphysis is incapable of bearing the weight without giving to some



FIG. 268. Radiograph of the hip joints of a girl aged 7 showing marked fragmentation of the epiphysis of the right femoral head with displacement of the most lateral fragment beyond the acetabulum. Osteochondritis deformans juvenilis coxæ.

degree and becoming moulded over the expanded and compressed extremity of the diaphysis. After the lapse of about 4 years

(12) *The cancellous structure of the epiphysis assumes the radiographic appearance of a normal bone.* Though the epiphysis and the adjacent diaphyseal extremity are compressed and deformed, the epiphyseal growth cartilage does not disappear as it does when the epiphysis and diaphysis are involved in an inflammatory process, or when a separation of the epiphysis has occurred. This is an argument against the suggestions that the process is one due to sepsis or displacement of the epiphysis (see Fig 270)

The study of a large series of these cases shows that the characteristic changes take place in bone which is within the capsule of the joint, *i.e.*, the epiphysis, the roof of the acetabulum and the proximal end of the neck of the femur. This rather suggests that the initial lesion leads to an alteration of the constituents of the synovial fluid within the joint, which as we have seen appears to be increased in the early stages. The radiographic appearances suggest that the condition of osteochondritis results in a redistribution of calcium only in those bones which are associated with the fluid contents of the capsule. Thus we see that the epiphysis takes up calcium while the end of the diaphysis loses it, and later when healing takes place the flow of calcium is in the opposite direction. The bones outside the capsule show little or no change unless the picture is complicated by disuse atrophy. We see a similar series of changes in osteochondritis of the head of the second metatarsal. This explanation does not hold entirely in cases of *Köhler's* disease of the tarsal scaphoid

growth cartilage or more distally situated in the neck away from the immediate proximity of the epiphyseal line (see Fig 271 A).

The prominence of signs (1) and (3) gradually increases the joint space remaining about the same.

The above three signs are usually to be found towards the end of the second month of the onset of symptoms.

In the author's series several cases occurred in which the radiographs showed only *these signs and the patient gave a* history of injury to the hip-joint area 2 or 3 months previously A number of cases have been submitted to the author several months after the first radiographic examination had been made, and these early signs had escaped detection This is another strong argument for the inclusion of both hip joints on the radiograph.



FIG 267 Radiograph of the right hip joint of a boy aged 18, showing condensation and flattening of the femoral head epiphysis and marked rarefaction of the juxta epiphyseal area of the neck. Osteochondriti deformans juvenilis coxæ

(4) *The dense epiphysis then begins to show the signs of compression and "impression fractures"* and this is followed during the next three months by

(5) *The appearance of fragmentation.* In this condition the epiphysis appears to be broken up into a number of dense fragments, and as the epiphysis has lost its fibrous element and capacity for withstanding the stresses and strains, it is friable, therefore

(6) *It is compressed and flattened still more* Some of the lateral fragments may at this stage be squeezed over the end of the diaphysis and beyond the lateral margin of the roof of the acetabulum.

(7) *Gradual absorption of the dense islands of bone occurs*, and

(8) *Compression and expansion of the proximal end of the diaphysis* which is now beginning to fix more calcium, and consequently becoming denser the osteoporotic zones are being obliterated or surrounded with dense margins.

The signs (4), (5) (6) (7) and (8) are to be found during the first year and a half of the disease (see Fig 268)

After the disease has been in progress about eighteen months, the radiographs will begin to show :—

(9) *A faint outline of a regenerated epiphysis in which the dense fragments appear to be undergoing absorption*, for their outline cannot now be distinguished Eventually

(10) *The last dense nucleus is absorbed, and in its place will be seen an area of relative osteoporosis*

(11) *The extremity of the diaphysis shows increased deposition of calcium and obliteration of the osteoporotic zone* (see Fig 266 B).

Removal of the latter is followed by recalcification This lesion has been mistaken for tuberculous caries and good illustrations were published by *Don King* and *Victor Richards* As recorded on p. 280 a lesion having a similar appearance may follow the sequence of changes of *Legg-Perthes* disease (see Fig 209)

Tuberculosis of the Hip Joint. The clinical features are usually very prominent including pain, marked limitation of movement, pain on manipulation, and marked wasting of the muscles of the affected limb. The radiographic appearances are distinctive (see Figs. 275–8)

Perhaps even more distinctive and contrasted are the differences in the radiographic appearances of healed bone tuberculosis and healed osteochondritis, for whereas the regenerated bone in osteochondritis takes on the internal structural appearances of normal bone the bone which has been involved in a tuberculous process never again appears normal because the signs of the bone "scar remain, and the cancellous trabeculation of the neighbouring bone has a coarseness of texture which can readily be distinguished from the normal When the avascular fragment is large as in fracture of the femoral neck or slipped epiphysis regeneration with coarse cancellous bone is not uncommon (see Fig 249)

Septic Arthritis. The clinical features of high temperature pain, swelling local heat and redness are distinctive. The radiographic appearances with this acute stage are those of normal bones but later general osteoporosis, with separation of the head of the femur as a sequestrum and erosion and absorption of bone are usually to be seen. Finally when the inflammatory changes have passed, bony ankylosis will have become established, and this will be apparent from the radiographic appearances

Endocrine Disorders. The shafts of the bones in these patients are usually characteristic, and a thorough clinical examination should make the diagnosis clear for the changes are symmetrical and of an equal age period, a very rare finding in osteochondritis (see pp. 269–70)

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Familial Dystrophy Defects in the femoral heads of a number of members of the family will be shown, perhaps with other defects (see pp. 268, 269).

Rickets. The bilateral deformities of the neglected rachitic patient will be recognised on clinical examination, and radiographs will show the typical changes which are quite distinctive from those of osteochondritis the latter may develop as an additional feature (see Figs 257–9)

Treatment. Unfortunately we have not yet discovered any treatment which will check or hasten the sequence of bone changes already described Our efforts must therefore be concentrated on reducing the subsequent deformity Most authorities agree that the limb should be immobilised if muscular spasm is present and as long as the patient is subjected to bouts of pain, but the means adopted by different surgeons to secure rest to the affected joint vary

Rest in bed for 6 months with fixation and extension on an abduction frame, followed by a further period of 6 months of fixation in a plaster spica, and finishing with another period of 3 to 6 months wearing a caliper is a plan adopted by the more conservative surgeons who consider that rest for a long time is essential. Other surgeons use only the plaster spica or the caliper for a few months. It has been stated by various authorities that the resultant deformity will be the same whether the limb is or is not immobilised. For example, the American Editors of the 44th Report of the Progress of

Certain variations occur during the progress of the disease —

(1) The acetabulum may develop similar changes, either concomitantly with, or subsequent to the healing of those seen in the epiphysis Following such changes the acetabulum is also compressed a feature which is most clearly indicated at the upper lateral border where the bone projects beyond the normal boundary (see Figs 248 A and B)

If the epiphysis is injured before the last dense island is decalcified and regenerated, this fragment (it is usually on the superior surface) may have its vascular supply impaired and fusion with the main epiphysis may be delayed or prevented This will give rise to the radiographic appearances simulating osteochondritis dissecans (see p 269).

In one case in the series those changes were not recognised until three years after the onset of the first signs.

If the pelvic wall of the acetabulum is affected, this may yield, and the condition of protrusio acetabuli develop, a condition which is, however more frequently associated with arthritic changes of the rheumatoid type.

(2) Following a complete decalcification of the affected epiphysis, regeneration of the epiphysis may occur from multiple osseous nuclei (see Figs 236, A and B)

The final appearances of the healed hip joint depend on the stage at which the disease was recognised, and the duration of rest of the affected bone from stress and strain during the plastic stage of the disease

Resulting Deformity In those cases in which the pressure has been evenly distributed over the plastic femoral head and acetabulum, the former is uniformly expanded over and with, the adjacent diaphyseal extremity and the latter flattened out and enlarged to accommodate the large femoral head. Where the lateral fragments of the epiphysis are squeezed beyond the lateral border of the roof of the acetabulum during the regeneration of the epiphysis, the displaced fragment also develops, and eventually comes to lie with its medial border against the lateral border of the roof of the acetabulum consequently it limits abduction (see Fig 271 C 4).

If the limb remains adducted during the plastic phase the medial aspect of the epiphysis may undergo more severe changes than the lateral aspect.

All those joints in which the disease has resulted in deformity of the articular surfaces work at a disadvantage, and are not capable of bearing the stresses and strains of the normal hip joint, consequently they develop the signs of traumatic arthritis at an earlier age than the opposite unaffected hip joints.



FIG. 260 Avascular fragment in head of femur

Differential Diagnosis

Osteochondritis Dissecans. This lesion usually found in adults, is probably due to trauma of a localised segment of the subarticular bone. The "loose body" in its bed may be symptomless and discovered by accident. If its vascularity is impaired it may appear dense, whereas the surrounding bone may show concomitant osteoporosis—a reaction to the adjacent necrotic fragment

Removal of the latter is followed by recalcification. This lesion has been mistaken for tuberculous caries and good illustrations were published by *Don King* and *Victor Richards* As recorded on p. 280, a lesion having a similar appearance may follow the sequence of changes of *Legg-Perthes* disease (see Fig 200).

Tuberculosis of the Hip Joint. The clinical features are usually very prominent including pain, marked limitation of movement pain on manipulation, and marked wasting of the muscles of the affected limb The radiographic appearances are distinctive (see Figs. 275–8).

Perhaps even more distinctive and contrasted are the differences in the radiographic appearances of healed bone tuberculosis and healed osteochondritis, for whereas the regenerated bone in osteochondritis takes on the internal structural appearances of normal bone, the bone which has been involved in a tuberculous process never again appears normal, because the signs of the bone "scar" remain, and the cancellous trabeculation of the neighbouring bone has a coarseness of texture which can readily be distinguished from the normal. When the avascular fragment is large as in fracture of the femoral neck or slipped epiphysis regeneration with coarse cancellous bone is not uncommon (see Fig 249).

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Certain variations occur during the progress of the disease —

(1) The acetabulum may develop similar changes, either concomitantly with, or subsequent to the healing of those seen in the epiphysis *Following such changes the* acetabulum is also compressed, a feature which is most clearly indicated at the upper lateral border where the bone projects beyond the normal boundary (see Figs 248 A and B).

If the epiphysis is injured before the last dense island is decalcified and regenerated, this fragment (it is usually on the superior surface) may have its vascular supply impaired and fusion with the main epiphysis may be delayed or prevented. This will give rise to the radiographic appearances simulating osteochondritis dissecans (see p. 260)

In one case in the series those changes were not recognised until three years after the onset of the first signs.

If the pelvic wall of the acetabulum is affected, this may yield, and the condition of protrusio acetabuli develop a condition which is, however more frequently associated with arthritic changes of the rheumatoid type.

(2) Following a complete decalcification of the affected epiphysis, regeneration of the epiphysis may occur from multiple osseous nuclei (see Figs. 236, A and B)

The final appearances of the healed hip joint depend on the stage at which the disease was recognised and the duration of rest of the affected bone from stress and strain during the plastic stage of the disease.

Resulting Deformity In those cases in which the pressure has been evenly distributed over the plastic femoral head and acetabulum, the former is uniformly expanded over and with, the adjacent diaphyseal extremity and the latter flattened out and enlarged to accommodate the large femoral head. Where the lateral fragments of the epiphysis are squeezed beyond the lateral border of the roof of the acetabulum during the regeneration of the epiphysis, the displaced fragment also develops, and eventually comes to lie with its medial border against the lateral border of the roof of the acetabulum, consequently it limits abduction (see Fig 271 C 4).



Fig 269 Avascular fragment in head of femur

If the limb remains adducted during the plastic phase the medial aspect of the epiphysis may undergo more severe changes than the lateral aspect.

All those joints in which the disease has resulted in deformity of the articular surfaces work at a disadvantage, and are not capable of bearing the stresses and strains of the normal hip joint, consequently *they develop the signs* of traumatic arthritis at an earlier age than the opposite unaffected hip joints.

Differential Diagnosis

Osteochondritis Dissecans. This lesion usually found in adults, is probably due to trauma of a localised segment of the subarticular bone. The "loose body" in its bed may be symptomless and discovered by accident. If its vascularity is impaired it may appear dense whereas the surrounding bone may show concomitant osteoporosis—a reaction to the adjacent necrotic fragment

Removal of the latter is followed by recalcification This lesion has been mistaken for tuberculous caries and good illustrations were published by *Don King* and *Victor Richards* As recorded on p 280, a lesion having a similar appearance may follow the sequence of changes of *Legg-Perthes* disease (see Fig 269)

Tuberculosis of the Hip Joint. The clinical features are usually very prominent including pain, marked limitation of movement, pain on manipulation, and marked wasting of the muscles of the affected limb. The radiographic appearances are distinctive (see Figs. 275–8)

Perhaps even more distinctive and contrasted are the differences in the radiographic appearances of healed bone tuberculosis and healed osteochondritis, for whereas the regenerated bone in osteochondritis takes on the internal structural appearances of normal bone the bone which has been involved in a tuberculous process never again appears normal, because the signs of the bone "scar remain, and the cancellous trabeculation of the neighbouring bone has a coarseness of texture which can readily be distinguished from the normal. When the avascular fragment is large as in fracture of the femoral neck or slipped epiphysis regeneration with coarse cancellous bone is not uncommon (see Fig 240)

Septic Arthritis. The clinical features of high temperature pain, swelling local heat and redness are distinctive The radiographic appearances with this acute stage are those of normal bones but later general osteoporosis with separation of the head of the femur as a sequestrum and erosion and absorption of bone are usually to be seen. Finally when the inflammatory changes have passed, bony ankylosis will have become established, and this will be apparent from the radiographic appearances

Endocrine Disorders. The shafts of the bones in these patients are usually characteristic, and a thorough clinical examination should make the diagnosis clear for the changes are symmetrical and of an equal age period, a very rare finding in osteochondritis (see pp 269–70)

Chondrodystrophies. A complete radiographic examination of the skeleton will show as in endocrine disorders symmetry of the changes at all ages and an enquiry into the clinical and family history should enable the observer to establish a diagnosis (see p. 286).

Familial Dystrophy Defects in the femoral heads of a number of members of the family will be shown perhaps with other defects (see pp. 208, 260).

Rickets. The bilateral deformities of the neglected rachitic patient will be recognised on clinical examination, and radiographs will show the typical changes which are quite distinctive from those of osteochondritis the latter may develop as an additional feature (see Figs 287–9).

Treatment. Unfortunately we have not yet discovered any treatment which will check or hasten the sequence of bone changes already described. Our efforts must therefore be concentrated on reducing the subsequent deformity Most authorities agree that the limb should be immobilised if muscular spasm is present and as long as the patient is subjected to bouts of pain, but the means adopted by different surgeons to secure rest to the affected joint vary

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evidence which confirmed the author's radiographic findings. In 1934 after correlating the serial radiographic appearance in some 71 cases, the writer was able to draw up the time-table which appears below showing the sequence of changes in twelve stages that characterise the disease from its inception to its complete healing. This sequence of changes has been confirmed by the subsequent examinations of 50 additional cases.

In 1934 *Danforth* published the case notes and radiographs of 8 patients who had been given freedom from weight bearing during the long period of bone plasticity and his findings lent further support to the suggestion made 2 years previously by the present author.

In 1938, *Waldenström* in a paper describing the first stages of coxa plana, stated "The most important consideration is to treat these cases purely conservatively. The patients should be given from one to two months rest in bed, after which they may be up and about on crutches for at least one year. However in a footnote, he stated that after the paper had been presented *Danforth* had shown him the radiographs of 2 patients who had been treated with rest in bed for one year or more and then were allowed to walk with crutches, the results in those 2 cases being better than those which he had obtained. *Waldenström* stated that he intended to try this method of treatment.

Gill, in 1940 stated: "But after Danforth's paper in 1934 we began to follow his method of prolonged rest in bed—when we are able to carry out this method without interruption the end results are practically perfect hips." His paper contained serial radiographs of a number of cases which confirmed not only the opinions that the author had previously formed from his study of serial radiographs, but also the time-table below which was incorporated in this book, published in 1935.

RADIOGRAPHIC APPEARANCES

Radiographic Appearances	Age of lesion judged from onset of first symptoms	Condition of the bone
(1) An increase in the density of the femoral capital epiphysis (2) A relative increase in the joint space (3) Osteoporosis of the diaphysis	2–3 months.	Becoming plastic.
(4) Compression and impression fractures of epiphysis (5) Appearance of fragmentation (6) Compression and flattening of fragments (7) Gradual absorption of the dense fragments (8) Compression and expansion of the proximal end of the diaphysis	3–18 months.	Plastic.
(9) First appearance of regeneration in the epiphysis in which dense fragments are undergoing absorption (10) Absorption of the last dense nucleus and the appearance of a circumscribed area of osteoporosis in its place (11) Increased deposition of calcium and obliteration of the osteoporotic zone in the diaphysis	1½–4 years.	Plastic.
(12) The epiphysis assumes the radiographic appearance of a normal bone	During or after the 4th year	Consolidated.

The occurrence of variations, such as the commencement of similar changes in the acetabulum or the opposite hip joints, at any stage of the primary lesion should also be borne in mind.

Orthopædic Surgery state: "We question whether it is often necessary to employ immobilisation even in the more acute stage of this condition The disease is frequently symptomless, and we do not believe that any evidence has been adduced to show that its course can be modified by treatment.

This opinion is supported by *Sundt*, who based it upon the results obtained when he immobilised 19 cases for 2 years, 16 cases for 1 year and allowed complete freedom to another 23 cases

From the study of the serial radiographs in 83 cases of this disease the author



Fig 270A. Legg-Perthes disease of the right hip joint, 2/10/41



Fig. 270B. Legg-Perthes disease of the right hip joint, 7/5/46. Little deformity with immobilisation.

concluded that radiographs supply very definite evidence in support of immobilisation for a long period. In a paper read before the Medical Society of London in March, 1932, the author demonstrated the radiographs of these cases and showed that: (1) for upwards of 4 years, until the last dense island had been replaced by normally ossified bone, the bone of the affected joint was plastic and could be deformed by pressure and (2) if the joint was immobilised during the plastic stage, although the series of changes was uninterrupted, organisation of the affected bone proceeded, and no deformity occurred (see Fig 270, A and B) In the subsequent discussion *McCrae Aitken* supplied clinical

would account for the statements previously referred to, namely that even after immobilisation for two years the final result differed little from that of the limb allowed freedom from restraint

The author would therefore suggest that the best results will be obtained in those cases which are recognised early and kept immobilised for as long a period as the radiographic appearance suggests plasticity of the bone—even to the length of four years, and he believes that there is little justification for immobilisation during only a part of the time that the bone shows plasticity In support of this contention he would point out that he has seen cases, showing all the stages in the radiographic appearances which he has described in patients who were immobilised as long as the radiographs suggested plasticity In these the final appearances of the hip joints have been indistinguishable from the normal. (*See* Ref *McCrae Aitken*)

In view of the poor condition of many of these patients, open air treatment supplemented with light baths and good wholesome food undoubtedly would be beneficial.

The operative measures devised and suggested by *R Whitman* have not been generally adopted.

Success in treatment would appear to depend upon early diagnosis and prompt, efficient immobilisation

HÆMOPHILIA

Patients suffering with this malady from time to time get hæmorrhages into one or more joints. The knee joint (see Fig 100) and the elbow joint are the most commonly involved, probably because they are most liable to injury The hip joint is occasionally involved, and also the shoulder Often the hæmorrhage into the joint is recurrent and



FIG 272. Pelvis and hip joints of a boy aged 12 years. Not marked shortening of femoral necks and broadening of the pelvis and acetabula. Chondro-osteo-dystrophy

frequently followed by an inflammatory reaction from which the joint may apparently completely recover Radiographs of such joints may or may not show bone changes. If the hip joint is involved in young persons, the vascularity of the femoral capital epiphysis may be impaired and it may show somewhat the same fragmentation seen in *Perthes* disease Radiographs showing these changes are used to illustrate the 1st and

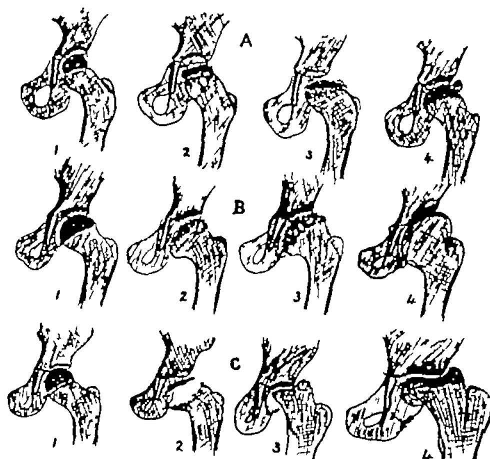


Fig. 271 Tracings of radiographs of three cases showing the appearance at different stages of osteochondritis deformans juvenilis coxae (Legg-Waldenström-Perthes-Calvé's disease.)

A 1 Relative density of the epiphysis no definite changes in shape. 2. Two months later showing flattening and increased density of the epiphysis. The neck is broadened and small cyst has appeared near the metaphysis and the extremity shows irregular ossification. 3. After another six months. Marked "fragmentation" of the epiphysis, the lateral part of which has been squeezed out of the acetabulum; expansion and shortening of the neck with still further disorganisation of the bone. 4 Three years later showing consolidation of the irregularly moulded epiphysis.

B. 1 Relative density of epiphysis. 2. Three months later. Flattening and irregular islands of dense bone in a lighter matrix. Expansion and shortening of the neck. 3. One year later. Marked fragmentation of the epiphysis, further expansion of the neck. Rounded excavations with sclerosed borders have appeared on the metaphyseal extremity of the neck. 4 Eight years afterwards. Narrowing of the superior joint space, sclerosis of the opposing subarticular bone. The acetabulum is flattened and increased in size to accommodate the enlarged head. Early osteoarthritic changes.

C. 1 Relative density of epiphysis. 2 Six months later. Condensation and marked flattening of the epiphysis. Area of decalcification of the expanded extremity of the diaphysis. 3 One year later. Complete absorption of the epiphysis—still further increase on the expansion of the neck. There is now about 1 inch of shortening of the limb, owing t upward displacement of the femur. 4. Four years afterwards. Marked irregularity of the articular surfaces of the hip joint.

The author's reason for using the term "plastic" in these stages is that he has followed up the radiographic history of such hips, and found that the affected bone has shown the pressure deformities of weight bearing as long as these changes persist. This

It is interesting to note that these patients usually show a deformity of the first lumbar vertebra with partial or complete dislocation In the type of dystrophy which I have named chondro-osteo-dystrophy the defective ossification involves the whole skeleton but other types have been seen in which only certain parts of the skeleton show definite changes.

For instance, in one type of chondro-dystrophy only the spine, shoulder and hip joints show marked defects in ossification.

Bilaterally one ossific centre may show more extensive changes than others (see Fig 201).

The neck of the femur and the epiphysis for the head may fail to ossify as in Fig 273. A patient in the series, 10 years of age, shows similar changes, the epiphysis of the head having not yet ossified

A type occurs in which the radiographs suggest that the dystrophic changes cease in infancy and that normal ossification subsequently proceeds. The appearance of



FIG. 274. Pelvis and femora of an achondroplasiac boy aged 2 years, showing thick, stunted pelvic bones and femora, wide joint spaces, but regular ossification as distinct from rickets and chondro-osteo-dystrophy

the skeleton in these cases so resembles the appearance seen in Achondroplasia as to suggest a relationship between the two conditions (see Fig 274)

TUBERCULOSIS

Early tuberculous arthritis may not produce any change in the bones of the hip joint which will show on a radiograph, so that the clinical signs and symptoms

2nd editions of this book and the papers of *Löhr* [1] *König* and *Peterson*. The degenerative changes may result in a deformity or complete destruction of the femoral head.

Montanari described a case, aged 2 in which the femoral head was completely destroyed.

CHONDRO-OSTEO-DYSTROPHY

In this condition the normal ossification of the cartilage of epiphyses does not take place. Radiographs show that whereas in the normal the cartilage is gradually ossified from a definite centre with a regular progressive development, in this condition the ossification is irregular so that islands of ossified cartilage are seen developing throughout the epiphysis and on the ends of the diaphysis (see Fig 272)

This defective ossification produces a structure which cannot withstand the super incumbent weight, and consequently the soft bone ends cannot develop their normal characters, growth is somewhat arrested and stunted The joint spaces are wider than normal, and as the joint surfaces do not receive the normal pressure stimuli, their development is defective In the hip joint, where weight bearing strain is placed upon the defective structures, marked deformity results, for not only may the ossific nuclei be destroyed and the acetabula expanded but in other cases with less severe signs of the



FIG. 272. Hip joints of a boy 8½ years of age, showing absence of ossification of the epiphyses and necks of the femora. Ten years later radiographs showed no sign of ossification in the head or neck. The outlines of the acetabula and femoral extremities were very irregular The shafts showed hypoplasia. Two similar cases have been serially examined. Marked upward displacement, as in un-united fracture of the femoral neck, occurred. Bilateral subtrochanteric osteotomy was unsuccessful in providing support and the patient showed progressive deformity

dystrophy elsewhere the head and neck are pressed almost beyond recognition as such, and the acetabulum develops to accommodate this altered structure. An example of this condition in a young boy of 4 years of age I [11] have published

Campbell [6] has recently published a similar case, a boy aged 8

The radiographic appearances seen in a boy aged 12 years are shown in Fig 272.

Silfverskiöld [1] published the details of similar cases.

Wilkie Scott [3] published radiographs of two sisters, aged 17 and 21 which showed marked shortening of the necks and deformity of the femoral heads.

this site may gradually extend beneath the deep fascia on the lateral aspect to the lower part of the thigh. Caseation in it will make it visible on radiographs In some cases the radiograph shows that the primary focus is in the acetabulum, and this focus usually rapidly extends, destroying the articular surface and a large area of surrounding bone. The floor of the acetabulum may be perforated by the pressure on the head of the femur and this in turn may be involved and destroyed (see Figs 276 A and B).



FIG. 276A. Radiograph of the pelvis and hip joints of a boy aged 4 years (23/8/27), showing early tuberculous erosion of the roof of the left acetabulum. General rarefaction of the femur but no localised erosion shown.



FIG 276B. Radiograph of the hip joints of the same patient as Fig 276A (9/7/31), showing commencing consolidation of the diseased structure and ankylosis of the great trochanter to the ilium

The disease may remain confined to the neck of the femur and healing ultimately take place without any involvement of the joint.

Periodic radiographs should be taken to determine the activity of the disease. In the early stages the advance may be very rapid, but when the process quietens down under the influence of rest and open air longer intervals are necessary before any change can be detected from the radiograph.

may be prominent with normal radiographic appearances, *i.e.*, there is a long latent negative radiographic period.[47] [48] The earliest radiographic sign may be a relative increase in the joint space of the affected side, but this will be apparent only if both hip joints are taken symmetrically placed on the same radiograph

After a short time, depending on the virulence of the infection and the resistance of the patient, the radiograph of the affected side may show any one of the seven types of change described on pp 206-9

A not uncommon form of the disease in the hip joint is that which I have classed as Type 6 (see Fig 278) In this there is a slowly progressive regular erosion of all the articular and other surfaces within the capsule resulting in a marked expansion of the acetabulum, to three or four times its normal size and a very attenuated femoral neck the head being completely destroyed. This lesion is sometimes referred to as a "**wandering acetabulum** (a term which should be reserved for a lesion seen in osteo-arthritis, see p 310) Rather should it be called an **expanded acetabulum**, for in it the upper end of the femur is permitted to wander

In contrast to this, tuberculous caries may exist in the bones near the hip joint without any definite clinical signs, and its existence may be discovered only when a



FIG. 273. Radiograph of the pelvis and hip joints of a girl aged 9 (22/12/28) showing dislocation of the left hip joint and irregular ossification of the neck of the left femur The patient fell 3 months before this radiograph was taken, but was able to walk with a limp; she complained of severe pain at nights. Tuberculous Arthritis.

radiograph is made, because the patient has sustained an injury to the joint or a disloca tion has occurred (see Fig 275) or because an arthritis has developed owing to a focus commencing in the bone and extending into the joint.

Radiographs for this purpose must be sharp and of good contrast In some cases, particularly in young children, radiographs taken without intensifying screens or the Potter-Bucky Diaphragm are advisable. A careful scrutiny of the relative width of the joint spaces, density of the two sides, the outline of the articular surfaces and the continuity of the bone trabeculæ should be made.

If the focus begins in the epiphyseal line of the great trochanter the trochanter may be completely destroyed without the hip joint being involved The abscess from

A negative radiographic report, as indicated by the author [44] does not exclude early bone tuberculosis, and if the symptoms persist, further radiographs should be requested at intervals, as the disease if present, will sooner or later be revealed by changes in the bone structure. It is equally important that, in those cases in which the radiograph showed no changes, further radiographs be taken at intervals even if the symptoms abate, as in osteochondritis marked radiographic changes may be present, though the major symptoms appear to have subsided. Radiographs taken at intervals throughout the treatment will help the surgeon to decide the length of time the lesion should be immobilised and will tend to prevent cases of simple arthritis being kept immobilised for 2 or 3 years.

If abscesses develop, no sign may be given on a radiograph but later when calcium is deposited in the abscess, its outline and density are sufficient to cast a definite shadow on a radiograph. Repair is indicated by an increase in the density of the bone in the neighbourhood and its more sharply defined borders. The trabeculæ of the healing and healed bone are much coarser than in the normal healthy bone. The presence of large gaps with irregular ill-defined or woolly margins in the coarse trabeculæ suggests latent foci. If bony ankylosis is proceeding the radiographs show that the bone striæ of the femur are continuous with those of the acetabulum.



Fig 275. Tuberculous arthritis. Serial radiographs of this patient show progressive erosion of the walls of the acetabulum, head and neck of the femur

Sequestra may be detected by the fact that they retain their density to a much greater extent than the living bone which is markedly rarefied. They do not have the sharp outlines of the sequestra seen in chronic osteomyelitis but have a coke-like appearance.

Dislocation of the hip joint in tuberculosis may occur early as a result of acute arthritis with effusion into the joint, or later as the result of destruction of the acetabulum (see Fig 275).

Of 60 cases of tuberculosis of the hip joint, 30 were seen in males and 30 in females. In the males, 16 showed left hip-joint disease, 13 right hip-joint disease, and in 1 both joints were affected. In the females, the right side was affected in 17 cases and the left in 13. In 3 cases the first radiographs showed a dislocation of the hip-joint. In 6 the disease appeared to begin in the epiphyseal side of the metaphysis, in 7 in the neck and in 12 in the walls of the acetabulum. In the remainder the bones were so involved that it was impossible to decide where the primary focus developed.

Whitman states that of 10,000 cases of bone tuberculosis during 20 years at the Hospital for Ruptured and Crippled, 3,320 were in the hip-joint. About half of the cases of tuberculous hip disease occur between the ages of 3 and 5 and about 85 per cent. in the first decade.

In the differential diagnosis from the other diseases of the hip-joint, the radio-

When tuberculosis begins as a focus in a bone, symptoms may develop before any alteration in the bone structure can be detected on a radiograph, but, before many weeks, definite erosion of the bone trabeculæ can be shown to have taken place. This

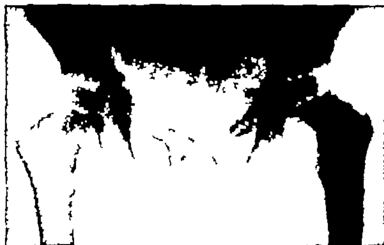


FIG. 277A. Radiograph of the hip joints and pelvis of a boy aged 8 years, showing a large area of erosion extending from the epiphyseal line to the intertrochanteric area, also a small area of erosion in the base of the epiphysis of the femoral head. Early tuberculosis. A radiograph of the hip joints taken by the author 8 months earlier did not show the slightest departure from the normal.

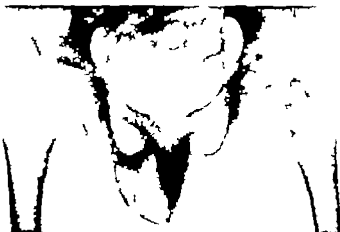


FIG. 277B. Radiograph of the same patient one year later showing extension of the tuberculous erosion in the femoral neck and epiphysis. The destructive process has progressed in spite of the fact that the patient was put on full modern treatment as soon as the lesion was detected.

is illustrated by Figs. 277 A and B—early symptoms had been present in this child for 4 weeks. In the radiographs taken during the first week of symptoms no bone change could be detected; later, after an interval of 8 months, the radiograph showed an area of erosion of the bone trabeculæ in the neck of the femur in the juxta-epiphyseal area.

excess of the erosion, and it gives an appearance quite the reverse of that seen in the radiographs of tuberculosis, where the bone erosion is the most marked feature and one which often progresses rapidly for a time in spite of rest and open air whereas the changes seen in syphilis take place slowly yet repair is more rapid and complete than we see in tuberculosis

Syphilitic lesions may be mistaken for *Ewing's* sarcoma because they may be asso-



Fig 280. Radiograph of the pelvis and hip joints of a baby aged 2 months. It shows an area of defective ossification on the upper and inner end of the left femur with a well-defined sclerosed border There is a definite thickening and sclerosis of the cortex of the upper half of the femoral shaft—"periosteal" thickening A small faint dot represents the nucleus of the epiphysis of the femoral head which is dislocated. The epiphysis of the right femoral head is well shown at this early age of 2 months. This was a first child no miscarriage, normal birth. The mother noticed when the child was a month old that the left leg was drawn up and that the child screamed when this leg was moved. Congenital syphilis. A further radiograph taken when the child was 2 years of age and had received antisyphilitic treatment shows a coxa vara deformity on the left side but no evidence of active bone disease



Fig 281 Radiograph of the pelvis and hip joints of a baby girl aged 14 months. It shows a fragmentation of the femoral necks with a bilateral coxa vara deformity The femora are slender and show an abnormal concavity on the inner side of the upper third. The femoral heads show poor calcification. The child was always small, and showed at the lower end of the radius the typical punched-out appearance of osteochondritis syphilitica. The appearances are similar to those seen in the shoulder joints of infants with scurvy in which outward displacement of the upper end of the diaphysis occurs through a tear in the periosteum distended by haemorrhage (see p 121).

ciated with multiple linear accretions of periosteal new bone perhaps adjacent to a localised area of erosion or disintegration of bone with some wisps of calcium in the adjacent soft tissues.

Fig 281 shows that syphilis has an effect on the growing bone, and in this case it has led to defective ossification of the necks of the femora and early development of coxa vara deformity The appearances of this case resemble the fragmentation of the neck of the femur seen in infantile coxa vara, but in the latter one does not see the atrophy of the femoral shafts as shown in this case

graphic evidence is the most important Radiographs of the chest may supply important confirmatory evidence; most commonly calcified glandular and other lesions rather than active pulmonary tuberculosis. From time to time the radiographic appearances of the active phase of Legg Perthes disease are mistaken for tuberculosis. The radiographic appearances and time-table are characteristic (see p 283)

Chondromatosis of the joint may produce changes in the articular surface suggesting caries (see p 209), but the most likely condition to confuse is lipoid granulomatosis



FIG. 279 Lipoid granulomatosis. Isolated lesions of this kind resemble tuberculous caries.

(see Fig 279). In this the lesions which respond to X radiation therapy are multiple and may be associated with the typical skull lesions (see Figs. 458A and 480A).

SYPHILIS

Syphilitic affections of the hip joint are much less common than tuberculous.

The youngest child showing definite syphilitic bone changes in the hip-joint area was only 2 months old

Congenital Syphilis is often revealed on the radiograph as an osteochondritis, and the commonest sites for such lesions to develop are the epiphyses of the head of the femur and the distal epiphyses of the humerus and the lower ends of the radius and ulna

Ossification in subperiosteal hematomata may be seen in the early weeks of life

It has been stated by several authorities that with these conditions the ossification is delayed, but Fig 280 which is the radiograph of a baby girl aged 2 months, shows very early ossification of the epiphysis of one femur although the epiphysis on the affected side has not commenced to ossify

The appearance of the upper end of the femur in this case resembles the appearances seen in syphilis of the long bones in adults—a general thickening and sclerosis of the periosteal bone with some irregularity of its surface The sclerosis and thickening is in

(Ewing's Tumour) sometimes produces a radiographic appearance which simulates that of syphilitic osteitis.

The massive and irregular sclerosis of syphilis of the ilium is shown in Fig 284



FIG. 283A. Bilateral syphilitic erosion of the head of the femur Dislocation of the right hip joint.



FIG 283B. Radiograph of the same patient as Fig 283A, showing marked regeneration of the femoral heads. The right has been nearly replaced in position.

Indirect results of syphilis may be shown by erosion of the ilium in the neighbourhood of the acetabulum by aneurysm

Crisp described 11 Iliac Aneurysms in a group of 551 and points out that gluteal aneurysms may press on the sciatic nerve quite early in their development and cause

If the condition of **Osteochondritis Syphilitica** develops in the head of the femur when the epiphysis is well-formed, it gives rise to softening of the epiphysis and this may be accompanied by a synovitis and partial or total luxation of the joint. The radiograph (Fig 282) shows femoral heads which have become subluxated and subjected to pressure against the superior lips of the acetabuli and have been moulded in this position.

The articular surface of the head of the femur may show erosion as in Figs. 283 A and B, and this may lead to dislocation. There is no suggestion of fragmentation of the epiphysis as in Perthes disease and there is no evidence of change in the juxta epiphyseal area as is usually seen in tuberculosis. The series of radiographs in this case shows the remarkable regeneration of the heads of the femora which followed anti-syphilitic treatment even after marked destruction of the articular surface. "Slipping" of the epiphysis of the femur due to syphilitic osteochondritis has been reported in cases of congenital syphilis. Bilateral localised erosion of the femoral head beginning as an expansion of the fovea have been seen in syphilitic patients and others with a negative Wassermann. In a case of the author's the femoral capital epiphysis on one side showed these changes and the other the typical appearances of Legg-Perthes' disease. *Lindemann* reported a case of congenital syphilis in which the radiograph of the patient at the age of 12 years shows a slipped epiphysis and 5 years later a further radiograph showed that the head and neck of the femur had been completely destroyed.



FIG 282. Radiograph of the hip joints of a girl aged 11 (10/1/29), showing destructive changes in the heads of the femora and the articular surface of the acetabula. The hip-joints appear to have become subluxated and the softened femoral heads subjected to pressure from the superior lip of the acetabula. Congenital syphilis (osteochondritis syphilitica).

In adults, syphilitic osteoperiostitis of the femoral shaft (Fig 402) is shown on a radiograph by the marked sclerosis and thickening of the affected bone usually the medial surface which is often roughened but the superficial irregular new bone formation is generally parallel with the shaft of the bone and sometimes has a crenated periphery. The chronic sub-periosteal abscess produces a dense spindle-shaped thickening with a small rounded abscess cavity on the medial surface just below the lesser trochanter (see Fig 225). In periosteal sarcoma this new bone formation shows as clearly defined spicules radiating out at right angles to the shaft of the bone. **Endothelial Myeloma**

n in a Charcot's joint He stated that he was doing some heavy lifting when he t a sudden pain down the back of his thigh and his leg gave way He massaged his with embrocation

In another case recorded by the author [44] a man of 30 who was under treatment tabes developed a limp A radiograph showed an extracapsular fracture of the moral neck the latter appeared to have been impacted into the base of the great ochanter but the edges of the fracture did not present the sharp outline of the recent acture but were rounded off There was small collection of amorphous calcium n unsuccessful attempt was made to cure union of the fragments by the sertion of a Smith-Petersen pin, but sorption occurred along the course of e pin and it had to be removed No sign f union followed this, a typical Charcot's oint developed, and a very severe oxa vara deformity resulted (see Fig 248)

The calcium set free during the stage f disintegration is later built up into a assive acetabulum (see Fig 280)

Radiographs before and after injury lustrate the relation of trauma to the citement of the sequence of changes hich occur in the neuropathic joint.

Another patient, a woman of 52 years f age, had had prolonged treatment in ospital for neuro-syphilis, and was ischarged when the condition was regarded as inactive. She sought further advice in April, 1940 because she was now getting severe pain in the left hip joint, and to a lesser degree in the right hip joint. The radiograph (23/4/40) showed osteo-arthritic changes in the right joint, but the changes in the left hip joint were not typical. The opposing bones were sclerosed but the acetabulum was expanded and the articular surface of the femoral head regularly worn down.



Fig 280. Radiograph of the hip joint of a woman aged 54 years, showing destructive erosion of the head and portion of the neck of the femur and the walls of the acetabulum with massive bands of new bone on the ilium running parallel with the roof of the acetabulum, also large deposit of amorphous calcium along the lateral surface of the upper third of the femur Charcot's joint—hypertrophic phase The calcium deposit and the extended acetabular roof organised and consolidated 3 years after it began to show signs of atrophy

On June 3rd, 1940, Mr F G Allan fixed the joint with a long Smith-Petersen pin, when he found the bone hard and sclerosed Radiographs immediately after showed an increase in the space between the articulating surfaces, but on August 24th, 1940 a further radiograph showed that in the meantime the nail had been broken and flocculent deposits of calcium had been deposited throughout the neighbourhood of the joint, and the sharp outline of the worn femoral extremity indicated the initial stages of a neuro pathic joint. A radiograph taken June 26th, 1941 showed the progression of the changes. The pathological changes in the hip-joint had also increased but they did not resemble those on the left side, nor the typical osteoarthritis. It is probable that trauma to the left would elicit a similar bony response to that shown by the right.

Burton [2] published an example in a girl of 17 in which the head and most of the

pain, which may lead to the diagnosis of sciatica. Not all aneurysms in this area are due to syphilis. The artery may be damaged by a blow crushing the vessel against the bone and an aneurysm may develop It is probably the most common site of traumatic aneurysm

Charcot's Hip Joint. In some cases the first indication of tabes dorsalis is a painless dislocation with a large effusion, in others a fracture most commonly in the trochanter



FIG. 284 Radiograph of the left hip joint of a man aged 27 It shows a complete destruction f the acetabulum and erosion and sclerosis of the femoral head with obliteration of the joint space The ilium is thickened, its structure shows irregular coarse sclerosed trabeculæ Syphilitic osteitis. Positive Wassermann.



FIG. 285 Radiograph of the left hip joint of a man aged 60 showing destruction of the neck of the femur A large collection of irregular calcified "mush around the joint. Charcot hip joint. Stage of disintegration.

or sub-trochanteric area. Suspicions as to its nature may be aroused by the relative absence of pain and the minor degree of trauma with which it is associated. The damage to the bone may be very considerable and yet the patient may fail to seek medical advice because of the lack of pain—this latter factor may actually mislead the medical practitioner and the fracture be missed Though the patient, whose radiograph is illustrated in Fig 285 attended hospital for treatment and presented at that time marked swelling and brawny œdema, with severe discoloration of the skin over the hip joint and upper thigh, the suspicion of a fracture was not aroused for a fortnight after he had been admitted to hospital. The clinical appearances then aroused the suspicion of sarcoma and a radiograph was taken which showed the stage of disintegra

one hip was spontaneously dislocated and while attempts were being made to reduce it, the opposite hip was dislocated The head of the femur was completely absorbed



FIG. 288. Radiograph of the hip joints of a boy aged 12, showing a pathological dislocation of the left hip due to acute arthritis.



FIG. 289 Septic arthritis with separation of epiphysis a a sequestrum.

In a large proportion of cases of acute septic arthritis the head of the femur separates as a sequestrum, as in Fig 280 or undergoes with the femoral neck fairly rapid absorp-

femoral neck were destroyed with the acetabulum while massive new bone formation of the ilium was present.

McCullum and *Warren* illustrate a case of bilateral Charcot s hip joints



FIG 287 Radiograph of a Charcot hip joint which developed in a patient with Paget disease of the pelvis. This had been erroneously diagnosed as a sarcoma

It has been estimated that about 5 per cent. of ataxic patients develop Charcot's joints.

The Charcot hip joint illustrated in Fig 287 was erroneously diagnosed as a sarcoma—the additional changes of Paget s disease had confused the issue

ACUTE ARTHRITIS

Acute arthritis of the hip-joint may occur in most of the infectious diseases. Typhoid, Paratyphoid, Abortus and Scarlet Fevers Measles Pneumonia, Gonorrhœa Spotted Fever Tonsillitis Small-pox, Puerperal Fever and Pyæmia. The clinical signs are much in advance of any radiographic signs, but where X rays are readily available, as with a portable apparatus, a radiograph may give very useful additional information.

The first radiographic signs are increase in the joint space (the distance between the articular surfaces of the bones), general rarefaction of the bones of the joint, and, later absorption of areas of the trabeculæ of the cancellous bone It has been estimated that in something like 23 per cent of the cases, the joint undergoes spontaneous luxation which would be obvious on the radiograph, though, owing to the pain of movement, this feature may not have been detected by clinical examination previously (see Fig 288).

Watson Jones [9] published the details of a girl aged 5 years who had pyæmia, in whom

one hip was spontaneously dislocated and, while attempts were being made to reduce it, the opposite hip was dislocated The head of the femur was completely absorbed



FIG 279 Radiograph of the hip joints of a boy aged 12, showing a pathological dislocation of the left hip due to acute arthritis.



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The first radiographic signs are increase in the joint space (the distance between the articular surfaces of the bones) general rarefaction of the bones of the joint, and, later absorption of areas of the trabeculæ of the cancellous bone It has been estimated that in something like 25 per cent of the cases, the joint undergoes spontaneous luxation which would be obvious on the radiograph, though, owing to the pain of movement, this feature may not have been detected by clinical examination previously (see Fig 288).

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phases of osteochondritis and consolidation of the diseased bone may occur without destruction of the articular surface

CHRONIC ARTHRITIS

With the passing of the acute arthritis in such joints the radiograph may show the narrowed joint space and the irregular sclerosed articular surfaces, as in Fig 291

Limited movement is possible with such joints but with use the opposing joint



Fig 291 Radiograph of the right hip joint of a woman aged 23 years, showing the changes of chronic arthritis, i.e., narrowing of the joint spaces, irregularity of the articular surfaces and sclerosis of the sub-articular bone. The patient had an acute arthritis 18 months previously

surfaces become eburnated and lipping of the articular margins can be detected on the radiograph, as in Fig 300.

Protrusio Acetabuli is the term which *Otto* gave to that condition in which the wall of the acetabulum are pushed into the pelvic cavity to form a protuberance on its lateral aspect. It is frequently bilateral but many unilateral cases have been seen. It is due to pressure being applied to the bone when locally it is unduly plastic. Anything which induces hyperæmia in the neighbourhood of the hip joints apparently produces an increased plasticity and that bone which is subjected to pressure, more particularly the walls of the acetabulum and to a lesser extent the opposing femoral head is deformed. The pressure applied is that of the superincumbent weight of the trunk when the patient is walking or standing The deformity consists of a protuberance due to a gradual inward thrust of the more resistant femoral head into its enveloping plastic acetabular walls and so into the lateral aspect of the pelvic cavity Its extent is dependent upon

tion In other cases, as in Fig 290, the epiphyses escape, the inflammatory lesion not extending beyond the metaphyses In chronic cases the detached femoral head may pass in an abscess cavity to the superficial tissues as in Fig 289 The sequestrated head, like all dead bone which has separated owing to sepsis retains its sharp contour and its calcium content, whereas the living bone is decalcified to a large extent and exhibits an irregular eroded outline.

While the inflammatory changes are active the involved bone exhibits marked rarefaction later when the acute phase has passed and residual inflammatory tissue



Fig. 290. Bilateral osteomyelitis of the upper third of the femur The density and detail of the involved bone indicate that the acute phase has passed. The right hip joint is dislocated. Note that the osteitis has not extended to either of the epiphyses and that the changes in the femur are limited to the upper third.

remains in a patient showing a good resistance to the infection the bone around the residual septic foci becomes sclerosed

If the infection is completely overcome and the septic foci are absorbed, the damaged bone undergoes repair and takes on the radiographic appearance of normal bone, though it may be rarefied if the infection has interfered to any great extent with function The radiographic appearances of acute sepsis in bone (see Figs 228 and 229) are not unlike those seen in some cases of endothelial myeloma and secondary carcinoma, but, while the clinical evidence is usually sufficient to differentiate between sepsis and carcinoma, it is of little help in differentiating between sepsis and endothelial myeloma. Unfortunately histological examination may add to the confusion Even if the hip-joint does not become dislocated its function is often impaired and the radiograph may show that the joint space is considerably diminished or even obliterated, indicating destruction of the articular cartilage Complete bony ankylosis may also result

Pneumococcal infection of the hip-joint may lead to complete absorption of the femoral capital epiphysis, erosion of the articular surface or disintegration of the epiphysis. Healing results in complete bony ankylosis in some cases. Radiographs of others in the healing phase may present appearances resembling those seen in one of the

detected if one examines the lateral ilio-femoral line as illustrated in Fig 232 As will be seen from Fig 202A which is a radiograph of R. A., a girl at the age of 8 years, in the early stage of this condition the radiograph may show some general osteoporosis with intensification of a few trabeculæ running parallel with the roof of the acetabulum the latter may appear to fuse with one another and form a more regular pattern as on



Fig. 203. Increase in the hip joint space 30/1/39 Patient aged 7 years.

the right of Fig 202A, which also shows a greater degree of protrusion. Two years later a further radiograph, Fig 202B, shows that the protrusion has increased so that the femoral head is much within the lateral iliac border Increased density is seen in all the walls of the acetabula, the trabeculæ no longer show the regularity seen in Fig 202A. No appreciable bending has occurred in the femoral necks.



Fig 204 Same patient 2/6/46 showing bilateral protrusion of walls of acetabulum.

A further example is shown in Fig 203 The radiograph of a boy This patient, R. C., aged 7 showed some increase in the joint space on both sides, slight flattening of the most medial surface of the femoral head but no material protrusion of the acetabulum. Seven years after the radiograph of these hip-joints, Fig 204 showed inward beak like protrusion of the acetabular wall at the junction between the pubic and iliac bones and definite flattening of the most medial aspect of the femoral head

the degree of localised plasticity and the intensity and duration of the applied pressure; it does not develop in patients kept recumbent though radiographs indicate considerable osteoporosis or localised inflammatory changes, nor in those conditions which radiographs show to be associated with an increase in the general plasticity of the skeleton. For instance, in the severe cases of rickets, osteomalacia, and osteogenesis imperfecta, the whole pelvis and the femoral neck show considerable bending, but this is not materially accentuated in the acetabular walls, *i.e.*, for this deformity we need bone with rigidity applied to localised plasticity in an area of bone which has surrounding resistance.

The condition is most commonly found in women in the 45–65-year age group, and has been regarded by some as a late stage in rheumatoid, menopausal or gonococcal arthritis—it is seen in these conditions, probably because patients are allowed to be up



Fig. 292A. Early protrusio acetabuli in girl aged 8. 18/8/44

and about at the stage when inflammatory changes are present instead of being kept recumbent until those changes have subsided. It may be found at an earlier age as the result of localised inflammatory reaction induced by injury or infection. It occurs in men under these conditions. More recently the author has discovered it in young



Fig. 292B. Same pelvis 6/6/40 showing that protrusion has advanced.

people before the age of 10 years. At this age as will be seen from Fig. 292A there is no added density in the affected acetabular walls, no deformity of the femoral heads and the condition is *bilateral*; *consequently the lesions* can be overlooked. It will readily be

detected if one examines the lateral ilio-femoral line as illustrated in Fig 232 As will be seen from Fig 292A, which is a radiograph of R. A., a girl at the age of 8 years, in the early stage of this condition the radiograph may show some general osteoporosis with intensification of a few trabeculæ running parallel with the roof of the acetabulum the latter may appear to fuse with one another and form a more regular pattern as on



FIG. 293. Increase in the hip joint space 30/1/39 Patient aged 7 years

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FIG. 294 Same patient, 3/6/46, showing bilateral protrusion of walls of acetabulum.

A further example is shown in Fig 293 The radiograph of a boy This patient, R. C., aged 7 showed some increase in the joint space on both sides slight flattening of the most medial surface of the femoral head but no material protrusion of the acetabulum. Seven years after the radiograph of these hip-joints, Fig 294 showed inward beak like protrusion of the acetabular wall at the junction between the pubic and iliac bones and definite flattening of the most medial aspect of the femoral head

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FIG. 202A. Early protrusio acetabuli in girl aged 8. 18/3/44.

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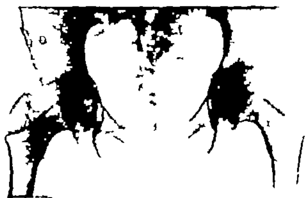


FIG. 202B. Same pelvis 8/0/40 showing that protrusion has advanced.

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FIG. 297 Unilateral protrusio acetabuli in a woman aged 45 years due to Paget's disease of the innominate bone The femur was manipulated under anaesthesia with fatal result.



FIG 298. Radiograph of the hip joint of a man, aged 50 showing protrusio acetabuli Note the moulding of the head of the femur and the sclerosis of the rim f the acetabulum. History of a f ll from a bicycle 3 years previously

The radiograph of the third case, D C., a girl aged 14 shows well-established protrusio acetabuli on the right side (patient's left), with less marked development of the deformity on the left side This asymmetrical development of the lesion in bilateral cases is usual and in most cases the right shows a greater protrusion and reaction than



Fig 293. Bilateral protrusio acetabuli in girl aged 14 years.

the left With increasing age the femoral head and neck also shows evidence of plasticity and instead of presenting a rounded margin which blends with that of the neck, the junction is angular or as in Fig 290, the articular surface may develop a projecting

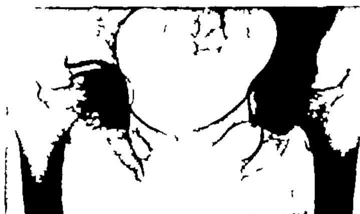


Fig 294. Bilateral protrusio acetabuli in woman aged 44

sleeve over the medial extremity of the neck Campbell [6] has published a case of bilateral protrusio acetabuli and his radiograph shows a remarkable moulding of the projecting surface of the heads of the femora.

The author found that bilateral cases of this nature were more frequent in women in the 45–65-age period (in 70 cases, 68 were women) In men trauma or sepsis were the cause for the lesion. It is common to find in such cases evidence of ossification in

ether due to trauma or inflammatory reaction, has a greater density than normal d is often massive it may constitute an obstacle during childbirth.



FIG 300 Radiograph of the hip joints of a man aged 24 showing bony ankylosis of the right hip joint with much thickening and sclerosis of the surrounding ilium with an area of rarefaction just above the acetabulum indicating a chronic bone abscess. Chronic arthritic changes in the left hip joint. Pneumococcal arthritis 10 years previously The bone abscess wa evacuated t operation.

The results of pneumococcal arthritis may be shown on the radiograph as being milar to those which we have described as chronic arthritis or as a complete bony nkylosis of the joint, with or without residua bscesses. Fig 300 shows the radiographic ppearance produced in a case of bilateral neumococcal hip-joint arthritis.

Following on septic arthritis the radiograph may show residual abscesses in any of the bony structures around the joint. These appear as areas of rarefaction surrounded by sclerosed bone (see Figs. 300 and 301) and unless treated they usually progress, and infection may again invade the cavity of the joint with the formation of a chronic septic arthritis.

Chronic septic arthritis may show a varied radiographic picture. The articular surfaces and surrounding bone may be markedly sclerosed or a gradual absorption of the head of the femur and the acetabular walls takes place In the subarticular area of rheumatoid and osteoarthritic joints large rounded cyst like areas of cancellous destruction may be found *J B Burt* has published an account of a patient, aged 31 who had gold treatment for rheumatoid arthritis 9 years previously A radiograph in 1935 showed a small "cyst" above the roof of the left acetabulum, the right being normal. In 1941 radiographs showed a round, large single cyst, about as large as the femoral head, just above each acetabulum, *i.e.*, they had



FIG. 301 Radiograph of the hip joint of a girl aged 20 showing a Brodie' abscess in the ilium just above the roof of the left acetabulum with woolliness of the articular surfaces and rarefaction of the head of the femur indicative of arthritis.

the lower lumbar and lumbo-sacral ligaments. Some patients show evidence of rheumatoid arthritis in other joints in others there is a history of gonorrhoea. Unilateral protrusion of the acetabulum may be produced by trauma, with or without radiographic evidence of fracture (fracture of the right acetabulum is more common than the left), sepsis of the femur or neighbourhood, or any other condition, producing plasticity locally which is insufficient to keep the patient recumbent when the bone is in that state, such as Paget's disease (see Fig 207).

The observations that the protrusion did not develop in patients whose illness

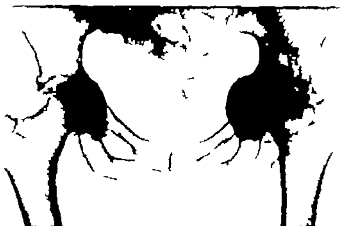


Fig 209A. Bilateral protrusio acetabuli, 20/8/31.



Fig 209B. Bilateral protrusio acetabuli, same patient 30/8/40. Note progressive changes.

necessitated recumbency and even in those ambulant cases in which the deformity occurred it did not increase once the inflammatory changes had subsided, suggests *that while there is any indication of plasticity or inflammatory reaction, the patient* should be kept recumbent But it must be appreciated that in this condition inflammatory reaction may recur when the bone will again become plastic, and capable of further deformity during weight bearing as in Fig 209 A and B

In the active phase the acetabular walls appear to be less resistant to trauma and may fracture. The new bone laid down in the protruding walls of the acetabulum,

examination The radiograph shows multiple loose bodies in the distended capsule of the hip joint and an area of erosion in the neck of the femur The joint space in the surrounding bone is normal. At operation over 1 000 irregular loose bodies of about the same size were removed These had a calcified nucleus and a cartilaginous covering The capsule was carefully washed out. Within a year a further growth had developed within the capsule This was not so large as the previous aggregate and had the appearance of a single ossifying chondroma. The lesion in the femoral neck appeared to have resolved

Paul also *Caird* have described similar cases.

OSTEOARTHRITIS

Radiology's chief claim to importance in the diagnosis of osteoarthritis is that the radiographic appearances are characteristic and can be readily distinguished by an experienced observer from other pathological changes in joints which may give somewhat similar clinical signs and symptoms. Unfortunately the condition often begins insidi



FIG. 303 Radiograph of the right hip joint of a man aged 53. It shows a small cyst-like development in the superior lip of the acetabulum, indicative of early osteoarthritis. No symptoms.

ously The patient experiences a certain amount of discomfort or aching in the affected joint after fatigue but this passes off with rest, and the patient may not be conscious of any discomfort for several weeks or months, during which time he is doing his normal work Fatigue of the affected joint due to an abnormal amount of work or strain again brings on the discomfort, but this passes again, with merely a night s rest

These bouts of discomfort because they are followed by periods of complete comfort do not often cause the patient to seek medical advice. Radiographs at this stage would show definite changes, but it is very rarely that they are requested (see Fig 303) In some cases the earliest radiographic sign is a prolongation of the articular

developed during the 6 years. Both hip joints showed atrophy of the cartilage, *irregularity and sclerosis of the approximated bony surfaces, as in Fig. 291*

On p. 78 reference is made to the development of these cystic areas in the carpus in Still's disease

LOOSE BODIES

The presence of loose bodies in the hip joint is rare

Köhler states that he has not seen any

A patient in this series, a man of 49 states that he was hit over the left trochanter by a piece of rock in 1915 during the attack on the Dardanelles. His radiograph, taken September 8th, 1932, shows an irregularity of the great trochanter and a large collection



Fig. 302. Osteochondromatosis of the hip joint of a woman aged 80 years. More than 1,000 loose cartilaginous bodies with calcification of the cores were removed. Note erosion of the femoral neck. *Within a year of removal a further single conglomerate mass as large as a hen's egg had developed.*

of rounded shadows extending from the rim of the pelvis to below the lesser trochanter

A case is illustrated by *Ehrlich*[1] in which the appearances were thought to be sarcoma and disarticulation at the hip joint was considered. A large collection of loose bodies was found in the bursa iliopectinea.

Osteochondritis dissecans occurs in the femoral head probably as the result of trauma to the normal surface or to the bone during substitution of avascular fragments (see pp. 197–0)

Osteochondromatosis. This condition is not often seen in the hip joint. An example is shown in Fig. 302. This is from a radiograph of a woman, aged 80, who complained of pain in the hip and knee joint, but nothing abnormal could be detected on clinical

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Fig. 302. Osteochondromatosis of the hip joint of a woman aged 30 years. More than 1,000 loose cartilaginous bodies with calcification of the cores were removed. Note erosion of the femoral neck. Within a year of removal a further single conglomerate mass as large as a hen's egg had developed.

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Osteochondromatosis. This condition is not often seen in the hip joint. An example is shown in Fig. 302. This is from a radiograph of a woman, aged 30, who complained of pain in the hip and knee joint, but nothing abnormal could be detected on clinical

of the acetabulum and indicates the progressive "wandering of the acetabulum" on to the lateral aspect of the ilium. The femoral neck often shows a buttress of new bone on its medial aspect.

These osteoarthritic joints, which have what might be called a radiographic history indicate that the condition is most frequently associated with trauma or damage to the articular surface by inflammatory changes.

The most characteristic radiographic features of osteoarthritis of the hip joint are shown in the weight bearing surfaces of the upper extremities of the joint, and may be summarised as follows —

(1) The appearance of small cyst like cavities in the juxta-articular bone, particularly in the superior lip of the acetabulum and the approximated surface of the femoral head. In some cases one of these cysts in the subarticular bone may be as large as the femoral head.

(2) Narrowing or obliteration of the joint space at this point—not a general narrowing as shown in the radiographs illustrating chronic arthritis of bacterial origin. This narrowing is due to localised destruction of the articular cartilage. Considerable erosion of opposing surfaces may be present.



FIG. 306. Radiograph of the left hip joint of a man aged 62. It shows obliteration of the superior part of the joint space; sclerosis of the opposing articular surfaces. Osteophytic growth around the margins of the articular surfaces—the detached osteophyte on the superior border resembles the os acetabuli. Osteo-arthritis.



FIG 307 Radiograph of the left hip joint of a man aged 33 It shows irregular dense sclerosis with areas of rarefaction "cyst"-like spaces Obliteration of the superior joint space and irregularity of the articular surfaces indicating erosion. History of an intertrochanteric fracture 17 years previously Osteoarthritis following severe trauma.

(3) Sclerosis of the subarticular bone associated with small areas of irregularity of the articular surface—an indication of eburnation and erosion.

(4) Lipping of the articular margins, particularly in the upper part, sometimes associated with much new bone formation due to osteophytic outgrowths.

surface as a cuff overlapping the extremity of the neck. But more commonly the early characters detailed later are shown. We know that such changes are present at this stage because of accidental discovery during radiographic examination for some other condition.

Later the bouts become more painful and disturb or prevent sleep but even such bouts may be followed by long periods of complete comfort.

Ultimately the pain during the attack is so severe that the patient consults a doctor and if a radiograph is obtained, it will at this stage generally show the characteristic appearances of severe osteoarthritis (see Figs. 304 and 305). The joint space will be greatly diminished, indicating destruction of the cartilage, the opposing bone surfaces will be sclerosed and eburnated or irregular due to erosion, often with the presence of cyst like structures in the neighbouring bone. The articular margins tend to be pointed and



Fig. 304. Radiograph of the left hip joint of a man aged 65. It shows obliteration of the superior part of the joint space, sclerosis of the roof of the acetabulum against the opposing articular surfaces and a tendency to subluxation produced by concentric layers of new bone laid down in the floor of the acetabulum. Early stage of "wandering acetabulum." Osteoarthritis.

Fig. 305. Radiograph of the right hip joint showing extrusion of femoral head; wandering acetabulum in osteoarthritis. A later stage than shown in Fig. 304.

"beaked" and there may or may not be definite osteophytes. At the superior lip of the acetabulum an ununited osteophyte which resembles the os acetabuli, may be present.

In the hip joint the appearance of subluxation due to erosion of the articular surfaces may be seen at the first radiographic examination. In other cases the radiographic appearances suggest that the head of the femur has been forced out of the acetabulum by successive layered accretions of new bone which have been deposited in the floor

Because radiographs taken 6 months after an injury show little change, it is not just to the patient to say that little damage has resulted from the injury. Although the changes produced by the damage in such cases are slow in development, their subsequent appearance will afford extreme surprise to clinicians who have not followed up the radiographic history of such a joint (see Figs. 307–309).

There would appear to be some other factor besides trauma concerned in the slow development of osteoarthritis, and it is perhaps reasonable to believe that toxic absorption is frequently the added factor, for most radiologists are familiar with the development of arthritis in patients in whom septic foci have been demonstrated.

Osteoarthritis of the same joint has been seen in several members of a family, suggesting a familial tendency. Bilateral familial coxitis associated with brachydactyly has been recorded by the author[14] (see Figs. 262 and 27).

This arthritis is probably associated with inflammatory changes in the articular surfaces rendering them susceptible to degenerative changes. If the articular surfaces have been injured by trauma they are more liable to be affected by circulating toxins than the normal joint surface and therefore more liable to subsequent osteoarthritic changes. The radiographic history of many of these patients supports this opinion.

The cyst-like changes in the neighbouring bone of an osteoarthritic joint to which *J. A. Thomson* rightly attaches much diagnostic significance—his "storm centres"—are degenerative structures. *Thomson* suggests that they may be produced by helminths. There is no helminth which produces such radiographic appearances or which restricts its activity to bone in the neighbourhood of joints. Nevertheless the author believes that the progress of the lesion can be checked and the pain avoided by rest. The taking of quinine (2–4 grains) daily he finds beneficial.

Fischer has suggested that they are due to protozoa, but there is no histological finding to support any other suggestion than degeneration. The fact that the eroded opposing bone surfaces do not fuse but continue to be worn away supports the opinion that the process is one of degeneration. Cysts are not always present. Their rounded form as in the bone abscess suggests osteolysis by some focal toxic agent.

Once these characteristic appearances of osteoarthritis have been shown on a radiograph, no improvement in the picture is seen following any treatment other than rest, after which some reparation may be noticeable in the cancellous structure.

Pain appears to be due to pressure or trauma on the extra articular hypertrophic villous structures which develop around the borders of the osteoarthritic joint. These are very sensitive to injury and may be the cause of very severe pain when nipped between the articular surfaces. They are very vascular and contain proliferating tissue elements, cartilage, and new bone. Though one is led to think that it is erosion of the articular surface which leads to the pain, we know that erosion may exist and yet the patient be free from pain for long periods, though movements on the opposing bone surfaces are taking place. In the more superficial joints, the extreme tenderness of this extra-articular hypertrophic tissue after trauma supports this view, and it would explain the response to treatment by radiation, though the subsequent radiographs fail to show any change or repair of the damaged articular surfaces. The intervals of freedom from pain may follow any form of treatment without the treatment being in any way responsible except for the rest which accompanies it. Pain and discomfort around the joint invariably come on after undue use of the joint, the more strenuous the work the worse the pain which follows the fatigue, but they are generally relieved by rest.

Success would appear to come only from treatment designed to rest the affected joint, or diminish the activity of the extra articular proliferation. Undue use of the joint can result only in aggravation of the condition. There is a widespread belief in

One or both hip joints may be affected. Bilateral cases often show similar erosion or cyst like changes. The articular cartilage may be destroyed and the approximated bony surfaces sclerosed and eroded without any sign of cystic degeneration or osteophytes in some cases the latter feature predominates.

The trauma may be due to strain of a mechanically defective joint, for example, unreduced congenital dislocation, or joints the architecture of which has been interfered with by disease, or injury or Perthes disease, or joints in which merely the articular surface has been wholly or in part affected by inflammatory or dystrophic changes as in arthritis.

Repeated blows or strains on the articular surfaces, each insufficient to cause more



Fig. 308 Radiograph of the left hip joint of a boy aged 19 who had an injury to the head of the femur 16 months earlier It shows a marked deformity of the epiphysis of the femoral head. Due to localised avascular necrosis.



Fig 309 Radiograph of the left hip joint of a man aged 33. It shows much new bone formation around the joint obliteration of the superior joint space with sclerosis of the articular surfaces. The appearance suggests reaction to localised avascular necrosis. The patient is an ex-professional foot baller who has had pain in his hip for several years.

than momentary pain are not infrequently associated with the development of an osteoarthritic joint—an example of which is the osteoarthritis of the hip joint seen in patients after much horse riding or football ng Severe injuries to the joint surfaces frequently lead to the development of localised avascular necrosis followed by osteoarthritis, a most important feature in medico-legal cases (see Figs. 307 and 309).

For instance radiographs taken soon after reduction of a dislocated joint frequently do not show the slightest departure from the normal If however radiographs are taken at intervals during several years, a large proportion of these joints will show the gradual development of the typical radiographic appearance of osteoarthritis

been requested and these have shown ossification of the muscles at the site of the trauma. In 2 cases a band of densely ossified tissue united the great trochanter to the ilium One might expect that this new bone would become absorbed as normal function was established but in the cases I have seen the new bone appeared to receive so much strain that it became more densely ossified than the normal femur which was relieved of some of its function These features are well shown in Figs. 310 A and B which are radiographs of a child who had a closed tenotomy of the adductor muscles performed



Fig. 310B. Radiograph of the hip joints of the same patient as Fig 310A (20/8/31) showing increase in the density of the new bone—it is now denser than the bones of the pelvis and the femora

for spastic paraplegia Myositis ossificans developed as a Y-shaped mass of ossified soft tissues which united the pubis and ilium to the upper third of the femoral shaft.

The radiograph (Fig 310 B), taken 12 months later shows that the new bone is denser than the femur and the bones of the pelvis, and that its density has increased during the year

Figs. 311 A and B, show that if a sufficient amount of the ossified tissue is removed to prevent it bearing weight or strain, the fragments left will become absorbed with the normal functioning of the bones.

The professional footballer may not show any abnormality in his hip joints during his playing years but very severe bilateral osteoarthritis is not unusual in later life (see Fig 309)

Dislocation of the hip joint may take place spontaneously It may in some patients be dislocated at will. The radiographs of such patients may not show any bone change even after repeated dislocation, but, as a rule, such joints become painful in adult life and radiographs will show evidence of arthritic changes.

Spontaneous dislocation of the hip joint has been seen in paralysis of the lower extremity in Tuberculous Arthritis, Typhoid Fever Rheumatism, Scarlet Fever Variola, Gonorrhœa Pneumonia, Influenza and Erysipelas. It may follow relatively slight trauma in tuberculosis, and the radiograph, as we have seen, may be the first evidence that this disease of the bone exists.

and outside medical circles, that exercise of such joints is necessary to prevent them becoming fixed. Rest never causes fixation. The joint becomes more free as a result of rest and pain is abolished. The surgeon secures this by nailing or excising the articular surfaces and securing fixation The old-standing unilateral case usually shows similar changes in the lower lumbar spine fixation of the femoral head will not abolish the symptoms due to this indeed it may put an added strain on it If rest would do the fixation the result would be better Exercise on the other hand leads to a progressive development of the osteoarthritis with its pain and disability

The radiographic picture of the osteoarthritic joint, though very variable, is characteristic, but other conditions such as **Osteitis Deformans** (Paget's disease) and **malignant disease** of bone give rise to signs and symptoms clinically indistinguishable though radiologically distinct. It is advisable therefore in all cases to make sure by radiographic examination that one is dealing with simple osteoarthritis this term must be reserved for the degenerative type of arthritis

Extensive degenerative changes in joints including atrophy and calcification of the cartilage and erosion of the subarticular bone to an even greater extent than in osteoarthritis is seen in cases with **alkaptonuria** (see Figs 484 A and B)

INJURIES

The radiograph of the injured hip may show no bone changes if it is taken soon after the injury has been sustained, but this is no proof that the bone or joint has not been injured

Radiographs of such hip joints made one or more years afterwards may show very



FIG. 810A. Radiograph of the hip joints of a boy aged 6½ (10/0/30), showing myositis ossificans—a Y-shaped band of new bone is seen uniting the upper third of the femur with the ilium and pubis. This ossification followed tenotomy of the adductor muscles for spastic hemiplegia.

definite evidence of injury to the bone, or joint, or the soft tissues of this area. I have radiographed the hip joint areas of footballers who have suffered recent injury in this region, and no bone injury has been shown on the radiographs taken, but, owing to the fact that these men have subsequently developed disability further radiographs have

of the proximal end of the femur This is a factor which is only too commonly overlooked, and the radiographic appearances of the apparently normal bones and joints for a month or so after are in some measure responsible. So little alteration in the characteristic outlines and detail may be shown in the radiographs taken several months after the reduction that the changes are undetected and the patient is encouraged to give the joint full function. The author has seen such radiographs exhibited in court by expert witnesses as evidence that the patient had sustained no damage to the joint, and that the disability of which he complained was "functional. However these changes, although apparently insignificant—perhaps a slight degree of osteoporosis with or without a faint hazy opacity within the capsule, due to a deposit of amorphous calcium—are the indications which, if they are neglected and the limb is permitted to function, presage the disintegration of the joint. Work or strenuous exercise would undoubtedly increase the extent of the damage. Whereas, if these changes were recognised early and the joint was immobilised until such time as the radiographic



FIG. 312. Radiograph showing disintegration of the femoral head due to avascular necrosis following traumatic dislocation. The patient was discharged from hospital 2 years previously with what appeared radiographically as a normal hip joint

appearances indicated a return to the normal, the joint would in a large measure be preserved. Because the radiograph may appear to the rehabilitation officer to be normal, the patient may be induced to use the limb in spite of the pain which accompanies use With this advice the patient endures the disability perhaps for a year or more, until at last he is forced to seek further treatment. The gravity of the damage can then be demonstrated, as in Fig 312

Fig 313, A, shows a normal bone and joint surface but Fig 313 B, taken 5 months afterwards, shows that marked changes have taken place in the bones and joints, yet these are trifling compared to the changes seen in Fig 313 C, which was taken 4½ years after the injury It is most important that these changes be fully appreciated by men doing medico-legal work

The author has stressed [49] that it is impossible to say in any given case the degree of disability which will develop as the result of trauma. There may be a long latent negative radiographic period

A study of the radiographs of dislocations suggests that the less the trauma in

Jones and *Lovett* state that the occurrence of hip dislocation in children is exceedingly rare, as it is much easier to loosen the epiphysis than to throw out the head of the femur

Radiographs show that separations of the epiphysis are much more frequent than



Fig 311A.

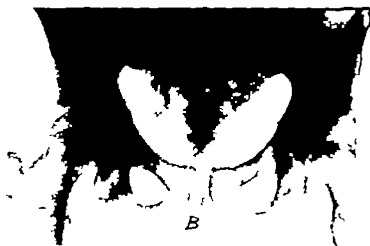


Fig 311B.

A. Localised myositis ossificans. Note the broad band of ossified tissue uniting the right ilium to the upper third of the femur Less marked ossification on the upper third of the left femur (10/1/26).

B. After surgical removal of middle segment of ossified tissue Note that the extremities of the ossified tissue are being absorbed. The left side now shows a normal appearance (18/2/27).

dislocations, but the former usually occur without any history of trauma; trauma of sufficient violence to fracture the neck of the femur usually leaves the epiphyseal union to the diaphysis intact

Dislocation of Hip Joint. The trauma associated with the production and reduction of dislocations of the hip joint is usually the cause of serious damage to the vascularity

Injuries to the acetabulum may not be detected on early radiographs, but later radiographs may show that the injured bone has given way to the pressure of the femoral head The condition of protrusio acetabuli may then be obvious, as in Fig 298 which shows the result of an injury 3 years previously

In these cases the radiographs suggest that there will be increasing changes and disability in these joints with the passage of time and in giving an opinion on the disability these features should all be taken into consideration



Fig 314 Radiograph of the right hip joint of a woman aged 60. It shows a fracture through the right hip joint with complete separation of the ilium from the ischium and pubis—the femoral head and neck occupying the gap; the lower extremity of the ilium abutting against the great trochanter Motor accident 5 years previously The patient is a very active woman whose walking ability does not suggest such a marked deformity

In some cases the femoral head and neck are pushed through the inner wall of the acetabulum, as far as the trochanters will permit as shown in Fig 314

Fig 314 shows an extensive fracture of the acetabulum with separation of its primary elements, yet a surprising stability enabled the patient to do a fair amount of walking with the aid of a stick

With such severe damage the joint is given rest, and it is not put to the severe test of the less injured joints, consequently the secondary changes are not so well developed

The repair of fractures in the neighbourhood is with bone more dense and massive than elsewhere

reducing the dislocations, the less the resulting disability. Injuries to the growing epiphysis of the head of the femur may result in faulty development of the epiphysis

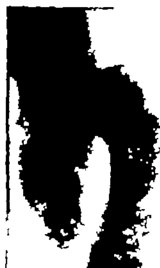


FIG. 318A. Radiograph of the left hip joint of a man aged 27 (23/3/27), showing a dislocation of the hip joint due to a fall.

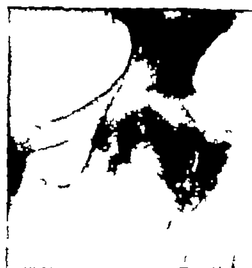


FIG. 318B. Radiograph of the same hip joint as Fig. 318A (17/8/27) showing rarefaction of the upper part of the femoral head and new bone formation in the soft tissues around the trochanters.



FIG. 318C. Radiograph of the same hip joint as Fig. 318A (14/12/31), showing consolidation of the new bone causing marked restriction of movement of the hip joint. The superior lip of the acetabulum is sclerosed.

or in avascular necrosis of the femoral head which leads to a destructive arthritis (see p. 257) as in Figs. 312 and 313, C.

examination it will be found that one form passes imperceptibly into another Consequently classifications tend to be largely a question of the individual observer's opinion on a relatively small amount of material rather than dependent upon mathematical accuracy Little has been gained from the substitution of the simple terms round, oval, flat, wedge-shaped or oblique by the quasi scientific expressions mesatipellic dolichopellic brachypellic, platypellic, etc other than the elevation of the terms above the appreciation of the general practitioner One group of writers state "We have used the characteristic long oval, round flat and wedge-shaped inlets to form the parent type" yet in the same paragraph state for simplicity we have described fine borderline or mixed types, the anthropoid-gynæcoid, the gynæcoid flat, the android anthropoid the android flat, and the android-gynæcoid," and still further in the paragraph "the term flat is preferable to the term platypelloid"" The variations have been well illustrated by *Caldwell, Moloy* and *Swenson*

DEFORMITIES OF THE PELVIS

Abnormalities and Deformities of the Pelvis are due to —

(1) Congenital abnormalities—Dysplasias and Dystrophies of the *skeletal system.*	(1) Achondroplasia.
	(2) Chondro-osteo-dystrophy
	(3) Multiple Chondromata *(Ollier)*
	(4) Multiple Exostoses.
	(5) Osteogenesis Imperfecta.
	(6) Albers-Schönberg's Disease.
	(7) Melorheostose.
	(8) Polycystic Dysplasia.
	(9) Polyostotic Fibrous Dysplasia.
(2) *Generalised bone or joint diseases.*	(1) Osteomalacia.
	(2) Osteitis Deformans.
	(3) Osteitis Fibrosa Cystica (Hyperparathyroid)
	(4) Infantile Rickets.
	(5) *Rickets associated with Renal and Cœliac Disease.*
	(6) Juvenile Polyarthritis.
(3) Localised disease or softening of the bones.	(1) Acute and Chronic Arthritis of the Hip, Sacro-Iliac joints and Symphysis Pubis.
	(2) Osteitis.
	(3) Localised Osteochondritis.
	(4) Cystic condition of the bones—Hydatid, Osteitis Fibrosa Cystica.
	(5) Primary and Secondary tumours.
(4) Disease and *injury* of the spine or lower extremity	
(5) Injury	
(6) Deformities during pregnancy	

CONGENITAL DEFORMITIES

Gross congenital deformities of the pelvis in the living child are rare Reference has been made to a case reported by *Wallace* of a tripedal baby in which the radiograph shows a third femur articulating with the ilium An interesting example of occult tail is illustrated by *Russell Reynolds* the radiographs showing a coccyx having six distinct

CHAPTER XIII

THE PELVIS

The pelvis consists of the two innominate bones, the sacrum and the coccyx Together they form a basin which helps to support the abdominal viscera and transmits the super incumbent weight of the head and trunk from the vertebral column to the femora.

OSSIFICATION

About the eighth week of fœtal life a centre of ossification appears in the ilium; this is followed during the next month by a centre for the ischium and by the end of the fourth month a centre for the pubis can be seen.

At birth the ossification of the three main elements of the innominate bones has reached the stage which indicates the mature form, though gaps consisting of cartilage still separate the bones At the acetabulum the three bones are united together by a Y-shaped cartilage and in this separate centres of ossification appear about the tenth to twelfth year These ultimately fuse to form the acetabulum about the age of 20 years. The ischium and pubis unite together about the eighth to tenth year

Secondary centres appear about puberty for —

(1) Anterior superior spine and crest of ilium.

(2) Posterior superior spine and crest of ilium.

(3) Anterior inferior spine.

(4) Tuberosity of the ischium.

(5) Symphysis pubis

(6) Spine of ischium

These usually fuse with the main bones at 20 to 25 years of age. The sacrum commences to ossify about the third or fourth month—the proximal bodies first. Centres for the neural arches and the costal bodies appear about 1 month later

Radiographs of the child at birth show that each of the five sacral vertebræ is represented by three definite bony nuclei one for the body and one on each side for the lateral processes Later epiphyseal nuclei for the lateral processes and the superior and inferior borders of the bodies appear but it is impossible to define them in the living by radiographs

The student is advised to consult *Fawcett's* paper on the ossification of the sacrum for further details

One nucleus for the coccyx may be seen at birth, but towards the end of the first year nuclei for the bodies and later for the cornua appear The details of these are rarely seen on radiographs taken during life Fusion of the bony elements takes place between 20 to 30 years of age but in some cases union between the segments is delayed while in others the coccyx fuses with the sacrum.

Very considerable variation exists in the form of the pelvis This may have an important bearing upon the measurements and their interpretation. Generally speaking it can be said that, with average dimensions, the more nearly the form of the birth canal approaches the circular in its section the more effective the dimensions. Attempts have been made to classify the various types of pelvis, but while it may be possible to separate certain extreme specimens into distinctive classes, it must be realised that anatomical structure is extremely variable, and if sufficient material is available for

examination it will be found that one form passes imperceptibly into another. Consequently classifications tend to be largely a question of the individual observer's opinion on a relatively small amount of material rather than dependent upon mathematical accuracy. Little has been gained from the substitution of the simple terms round, oval, flat, wedge-shaped or oblique by the quasi-scientific expressions mesatipellic, dolichopellic, brachypellic, platypellic, etc. other than the elevation of the terms above the appreciation of the general practitioner. One group of writers state "We have used the characteristic long oval, round, flat, and wedge-shaped inlets to form the parent type" yet in the same paragraph state "for simplicity we have described fine borderline or mixed types, the anthropoid-gynæcoid, the gynæcoid flat, the android anthropoid, the android flat and the android-gynæcoid" and still further in the paragraph "the term flat is preferable to the term platypelloid". The variations have been well illustrated by *Caldwell*, *Moloy* and *Swenson*.

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appear to be drawn over to the sound side *Cilliatt* has published radiographs of a case presenting a pelvic deformity of this type.

A deformity of the pelvis presenting somewhat similar radiographic appearances has been seen by the author in a woman after a fracture of the pelvis with separation and fusion of one sacro-iliac joint.

Irregularities of the Pelvis due to Dystrophies of the Skeletal System. In **Chondro-osteo-dystrophy** before puberty the pelvic canal is narrowed, the joint spaces are considerably widened, as are also the spaces between the ilium ischium and pubis at the acetabulum. After puberty the pelvic joint spaces are narrowed and irregular in outline: fusion occurs in bones which have exhibited defective ossification and which have been compressed because of this the mature pelvis having a broad squat appearance associated with malformed defective joints contrasts with what occurs in Achondroplasia, in which the radiographs show a broad squat pelvis but joints possessing regularity of outline and development (see Fig 274)

In **Osteogenesis Imperfecta** the pelvis is thin and soft and is bent by the weight of the trunk, the pull of the muscles, and, to some extent, by the upward thrust of the femora. Consequently the sacrum and lower lumbar spine pushes forward and downward into the true pelvis, bending in the ilium so that the vertebral spinous processes are on a more superior plane than the bodies. The walls of the acetabulum are pushed into the true pelvis and the brim becomes somewhat triradiate in shape. If associated with a scoliosis the softened plastic bone of the pelvis is drawn or pushed into a most contorted shape with obliteration of all the normal outlines. It has a wind-swept appearance The pelvic wall of the acetabulum on one side may be compressed against the sacrum, and the other side widened to accommodate the pelvic viscera. The author has illustrated this[49]

In cases of **Multiple Exostoses** the brim and cavity of the pelvis may be distorted by irregular bony masses. In some cases when no definite exostoses of the pelvic bones are to be seen, the pelvic brim is deformed, the most noticeable feature being its triangular shape—the normally curved lateral walls appearing to be straightened out.

In **Progressive Myositis Ossificans** spurs of bone may project into the pelvis from the bony walls

In marble bones (**Albers-Schönberg's Disease**) the bones show great density with little structure in the adult, but in the young child bands of dense bone may be seen at the periphery only No great departure from the normal shape is to be seen.

Numerous islands of condensed bone ovoid in shape and ½ to ¼ inch in their greatest diameter may be seen scattered throughout the pelvic bones in cases of **Osteopoikilie** (see Fig 316) In some cases a number of dense lines of condensed bone a variable distance apart but parallel to the growing periphery may be seen, as in cases described by *Goetsky* and *Welke Kemkes* also *Gotteslieben*. Lines of dense bone radiating in the direction of the main trabeculae are shown in Fig 316 B Somewhat similar lines have been illustrated by *Voorhoeve* while more recently *Brockman*[1] has shown a case in which these dense lines showed a more irregular radiating distribution; such distribution is found in cases of *Ollier's* disease

In the condition described as **Melorheostose** by *Léri* irregular masses of condensed bone may be shown within and projecting from the surface of the bone giving a radiographic appearance which suggests a chronic inflammatory process or a sclerosing sarcoma. *Meisels*[2] has described such a case (a woman of 27). The radiographs of this case show large bosses of compact bone involving the pelvis, particularly around the hip joints causing marked limitation of movement.

segments Failure of development of the pubis is seen in some cases of **Cranio-cleido-dysostosis** and is associated with epi and hypo-spadias. Bilateral protuberances from the middle third of the posterior surface of the ilium resembling horns are occasionally seen. These are associated with defective development of the patellæ. *F E Fong* has illustrated a case similar to that in the author s practice.

The commonest developmental irregularities are to be seen in the processes of the first and second sacral vertebræ. The condition of **Spina Bifida Occulta** may be indicated by a dimple a tuft of hair or nodular irregularity of the skin overlying the defective spine but in some cases the radiograph gives the only indication.

Reference has been made in dealing with neurotrophic lesions of the foot to spina bifida occulta

Constantini Bernasconi and *Cosniot* have recorded in a child of 12 incontinence which disappeared within 8 days of opening up the narrow nerve channel by laminectomy

Stropeni recorded a Spina Bifida Occulta associated with incontinence in a boy of 10 who had had symptoms for 16 years At operation a fibrous band replaced the laminæ and compressed the nerve: the removal of this band led to marked improvement.

Denel has recorded an **Anterior Sacral Meningocele** in a youth of 20 years, which was removed successfully

Many variations occur in the ossification of the first sacral vertebra due no doubt, to its position in the transition between the mobile lumbar and the fixed sacral vertebræ. In some cases the first sacral vertebra is almost indistinguishable on the radiograph from the fifth lumbar—the so-called **Lumbarisation** of the first sacral vertebra. This irregularity may be unilateral or bilateral It may be associated with spina bifida occulta.

Irregularities of the acetabulum and the development of a false acetabulum on the dorsum ilii are seen in cases of congenital dislocation of the hip joint.



FIG 315. Unilateral congenital deformity of sacrum producing Nägeli-type of pelvis.

A characteristic deformity of the pelvis due to failure of development of the ala of the sacrum on one side and subsequent fusion of the ilium to the defective sacrum was first described by *Nägele* The affected side of the pelvis is flattened, its brim is narrowed and shows a marked obliquity The defect is detected clinically by a considerable reduction in the oblique diameter which is measured from the sound side, but the defect generally reduces the measurement of the pelvic canal and Cæsarean section of the affected pregnant woman is considered advisable.

In the young child the sacral defect is associated with a definite gap between the sacrum and the ilium and the latter appears to become elevated on the affected side (see Fig 315). The sacrum being held by the sound sacro-iliac joint attachments may

The aetiology of this condition is unknown. It is very slowly progressive and of the nature of a bone dysplasia.

Irregular single or multilocular cyst like expansions may be seen localised to one



Fig 317 Polyostotic fibrous dysplasia. Patient had isolated lesions in head and limb bones. See Fig 444

or more sections of the pelvis in polyostotic fibrous dysplasia and in polycystic dysplasia (see Fig 317).

DEFORMITIES OF THE PELVIS DUE TO GENERALISED BONE DISEASE

In the bone diseases **Osteomalacia, Osteitis Deformans, Osteitis Fibrosa Cystica (Hyperparathyroid), Renal Rickets, Osteogenesis Imperfecta** and **Carcinomatosis**, the bones of the pelvis cannot withstand the normal stresses and strains and consequently marked deformity of the pelvis may occur

Osteomalacia. The bones of the pelvis in osteomalacia show the most characteristic appearance of this condition, marked osteoporosis, pressure deformity and sometimes pseudo-fractures, the so-called Looser zones, most commonly in the pubic bone (Fig 3*0)

The bones, being soft, yield to the weight of the trunk, the upward and inward thrust of the femora and the pull of the muscles and the strong ligamentous attachments. The upper sacral vertebrae are pushed forwards and downwards, the lordosis of the lower lumbar spine is increased to such an extent that the spine of the fifth lumbar vertebra may be directed almost vertically above the body The superior surface of the sacrum faces directly forwards so that the antero-posterior radiograph shows the outline of this surface as in Fig 260.

The sacrum is acutely flexed at the level of the second or third body to such an extent that the anterior surface of the lower bodies and the coccyx may face and be parallel with the anterior surface of the first and second sacral bodies (see Fig 308).

The weight of the trunk and the lordosis of the lumbar spine force the sacrum and

Fig. 316A. Radiograph of the pelvis and hip joints of a man aged 28, showing dense islands of compact tissue throughout the cancellous bone. Osteopoikilie.



Fig. 316B. Radiograph of pelvis of boy with femora showing unusual form of osteopoikilie. *Dense islands are shown in the femoral capital epiphyses* but in addition the cortex and

whole of one side of the pelvis in a patient who 10 years later exhibited the osteoporotic type.

(2) The Osteoporotic Type. In contrast to the above th second type is what I have previously called the fibrous type for the affected bone is less dense than the normal bone its cancellous trabeculæ pattern is much coarser than normal and the individual trabeculæ are irregular in disposition and direction.

The affected bone is expanded and even more plastic than the former type so the pelvic brim may become triangular in shape except for the protruding acetabuli

(3) The Lithocystic Type. The third type is a mixture of the two preceding types for in it many of the main trabeculæ appear to have fused, so that the brim and the main lines of stress are dense and devoid of cancellous trabeculæ, but throughout irregular gaps of relative transparency occur in which coarse trabeculæ are revealed.

This type does not show the same degree of plasticity of the two former but that it possesses this property is revealed by the flattening of the sides of the pelvic brim. The latter does not, however take on the triradiate appearance, though a degree of protrusio acetabuli may occur It is this latter type which is difficult at times to differentiate from carcinomatous metastases and in which the recognition of sarcomatous metaplasia may be difficult.

When the sacrum is the first bone involved and the case is observed over a length of time by periodic radiographs, the bone change appears to spread into the ilium as if it were part of the same bone

When only one side of the pelvis is involved the radiograph shows expansion of the bone and straightening out of the curved pelvic brim on that side so that the pelvis becomes asymmetrical. Gradually as the condition becomes more severe the bone softens and its shape is distorted, and in the final stages the pelvic brim becomes triangular in shape.



FIG. 318A. Hyperparathyroidism. Early stage, 23/1/33.

lower lumbar vertebræ forwards and downwards towards the floor of the pelvis, so that the third lumbar vertebra may sink to the level of the iliac crests.

The strong ligamentous attachments to the posterior spines of the ilium on both sides cause the latter to be bent forward while the upward thrust of the femoral heads pushes in the lateral walls



FIG. 318. Paget disease of the pelvis. (1) Osteolithic type (2) Osteoporotic type. (3) Lithocystic

Radiographs show that these deformities are frequently associated with irregularity of the sacro-iliac and hip-joint surfaces due to arthritic changes.

Photographs of the "Broughton" pelvis, *a specimen of osteomalacia in the Museum of* the Royal College of Surgeons, are to be found in my paper* on lumbo-sacral deformities.

Very considerable degrees of **Osteoporosis** *of the* pelvis are seen without the plastic deformities of osteomalacia. They are probably of a more acute nature and associated with disability necessitating recumbency

Osteitis Deformans. The pelvis is one of the most frequent sites to show the first changes of *Paget's* disease

Three types of change may be distinguished in the pelvis (see Fig 318) :—

(1) **The Osteolithic Type** Uniform increase in density with obliteration of the detail of the cancellous trabeculæ—the area of the film having a ground-glass appearance. One or both sides of the pelvis may show the change, and this may or may not be associated with similar changes in the sacrum or femora. The dimensions of the affected bone are all increased, consequently the pelvic brim is diminished When the whole of the pelvis is involved and, notwithstanding the obvious density the bone has become some-
w … id is deformed by tl
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p. 556 Some cases … h
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(see p 557)

This type may prec … of … ype—

ligamentous attachments to the posterior spines of the ilium, these are also pulled forward *The upward thrust of the femoral heads* pushes in the lateral walls of the pelvis. The sacrum may be bent to a right angle at the level of the second or third bodies, the lower bodies and coccyx projecting forwards (see Fig 250)

Though radiographs of the young patient may show a tendency to this triradiate deformity further radiographs, taken after treatment, show that considerable correction of the deformity is possible *The acute flexion of the sacrum may persist* (see Figs 252 A and B)

Similar deformities of the pelvis are to be seen in type B renal rickets as in this condition also the bones are softened and rarefied The deformity of the pelvis in grave cases may be more severe than in the extreme cases of osteomalacia The crest of the



Fig. 320 Old-standing renal osteodystrophy Note zone of absorption in pubic bone and ilium—so called Looser zones.

ilium in the adolescent with this type of renal rickets frequently shows a fluffy margin about ¼ to ½ inch in depth, in which striations are to be detected perpendicular to the margin.

Multiple pseudo-fractures may be shown as in Fig 320 See also *Milkman's* paper

In type A **renal rickets** the only departure from the normal radiographic appearances is an apparent increase in the sacro-iliac joint space and blurring of the outline of the joint. In well-established cases of **Idiopathic Steatorrhœa** all the bones show a characteristic coarse cancellous pattern with no compact tissue but perhaps only slight *bending* (see *Fig* 321)

In juvenile polyarthritis (**Still's Disease**) the antero-posterior diameter of the pelvic brim may be diminished

Deformities of the Pelvis due to Localised Disease of the Bone are not infrequent

Protrusion of the walls of the acetabulum into the true pelvis may follow **Acute**



FIG. 310B Hyperparathyroidism. Same patient 22/8/36 Note the marked development in the cystic changes in the spinous process of 4th lumbar vertebra and in bones of pelvis.

Early stages of the disease do not produce any characteristic symptoms and it is only when the patient has been radiographed that the true nature of the condition is ascertained Thus it is that the radiologist [19] first discovers this condition during the radiographic investigation for suspected disease of the urinary tract, lumbago or sciatica.

Hyperparathyroidism. In this condition the pelvis develops the distorted shapes seen as the result of other pathological softenings of the bones.

The bone shows general osteoporosis, and large areas may be devoid of cancellous trabeculation and may show small deposits of amorphous calcium. Multilocular cystic areas with a few thickened septa may show expansion The remarkable development of these cystic areas is shown in Figs. 310 A and B.

Incomplete fractures may be seen in the superior and inferior pubic rami.

Gross Albenhausen's radiograph shows a large cyst of the ischium and protrusion of the head of the femur into the pelvic canal.

Polycystic Dysplasia. One or more areas may show a multilocular cystic appearance, the other bone being normal in density and structure.

Polyostotic Fibrous Dysplasia. The whole or part of the pelvis may show expansion and deformity The involved segment shows no cancellous structure but has a ground glass-like appearance and is little less dense than adjacent normal bone (see Fig 317).

Rickets. Rickets is the commonest cause of deformity of the pelvis The bone is softened during the active phase, and yields to the superincumbent pressure

The extent of the deformity is dependent upon the duration of this phase of disorganisation of bone growth, and the treatment received during it.

In mild cases the general outline of the pelvis may be preserved, but its capacity or one of its dimensions may be diminished

In the severe cases which have been neglected a triradiate deformity of the pelvis develops, because the sacrum is pressed downward and forward, and owing to its strong

Widespread **Osteitis** of the ilium ischium and pubis is uncommon. The lesion is usually localised to the neighbourhood of the joints, but foci in the vicinity of the ischial tuberosity are not uncommon.

Following septic infection of the joints bony ankylosis is frequent.

Occasionally a Brodie's abscess develops in close proximity to a joint which was infected but has been symptomless for a year or more, and, later the joint may be reinfected—examples of such cases have been seen. In one case recovery of joint movements appeared to follow a septic arthritis, but the radiographs showed a localised change which suggested a residual abscess just above the acetabulum. Radiographs taken 2 years later for the purpose of this description showed that the joint surfaces had been destroyed, though no acute illness had occurred (see Fig 301). In the acute phase of pyogenic osteitis there is marked osteoporosis, and the involved area has a diffuse margin which cannot be defined. In some cases separation of a sequestrum occurs In the chronic stages osteosclerosis predominates.

Tuberculous Osteitis may commence in the superior lip of the acetabulum, near the margin of the sacro-iliac joint, the symphysis pubis, or the ischial tuberosity In the early stage the focus is usually clearly defined on the radiograph as an area of erosion though the bone shows general osteoporosis.

Later the osteoporosis is more severe and an amorphous or coke-like sequestrum may be shown at the original focus.

In the chronic stage scattered deposits of calcium may be shown throughout the involved area or in the abscesses which have burrowed into the soft tissues.

Large areas of the ilium may be destroyed. As the process heals, the bone of the area shows a very coarse open trabeculation—the trabeculæ at this stage being clearly defined

Following prolonged fixation for tuberculous caries of the spine, radiographs of the pelvis sometimes show complete decalcification of the central portion of the ilium only a thin zone of bone marks the outline of the crest and lateral border

Syphilitic Osteitis may involve the whole of one side of the pelvis, the chief distinctive radiographic feature being irregular osteosclerosis and hyperostosis (see Fig 284) Isolated gummata of the bones may occur : these are to be distinguished from Brodie's abscesses by the massive bony reaction which usually accompanies the former

Osteochondritis of the Pelvis. Osteochondritis of the bones of the pelvis has been seen in the regions of the symphysis pubis, the ischio-pubic junction, and the superior lip of the acetabulum in each as a separate entity and in the last-named site in association with Legg Perthes disease, or with slipped epiphysis.

The condition occurs in children from the ages of 6 to 14 and is associated with pain in the early stages.

The radiographs show islands of condensed bone in a matrix which is rarefied and deformed by pressure

In ischio-pubic osteochondritis the junction may present an area of cancellous destruction. Later the area may appear to be expanded and cyst like, and within this there may appear to be a small sequestrum.

Illustrations of the ischio-pubic osteochondritis are shown in the paper by *Wulfing and Zeitlin* The destructive process may extend to the symphysis. These lesions produce clinical signs and symptoms which may be mistaken for hip-joint disease

Similar changes have been noted in the region of the sacro-iliac joint. As in other sites osteochondritis results in softening of the affected bone which is *subsequently* moulded by the stresses and strains to which it is subjected.

In this way the condition of protrusio acetabuli, deformities of the sacro-iliac

Arthritis or Traumatic Arthritis of the hip joint thus is it seen in cases of Juvenile Polyarthritis, Rheumatoid Arthritis, Post-menopausal Arthritis, and in some cases of Gonococcal or Pneumococcal Arthritis. It also occurs in Osteochondritis of the walls of the acetabulum, induced by trauma or neighbouring inflammatory changes.



Fig. 321. Idiopathic steatorrhoea. Characteristic type of osteoporosis. Coarse cancellous pattern. No compact tissue see Fig 31.

Marked osteoarthritic changes with bulky osteophytes have been seen in the symphysis pubis After fusion of this joint in rheumatoid arthritis large areas of cancellous destruction may be seen.

In Tuberculous, Syphilitic, or Pyogenic Arthritis of the hip joint, the pelvic wall of the acetabulum may be perforated by the head of the femur

Tuberculous syphilitic or pyogenic infection of the sacro-iliac joint may be the cause of obliquity of the pelvis, either by displacement during the acute phase of the disease or following fixation of one side by bony ankylosis

plasmocytoma and hyperparathyroidism. Pseudo-cystic changes may be seen in osteitis deformans, polyostotic fibrous dysplasia and metastatic carcinoma, particularly from primary in the uterus.

Hydatid Cysts of the bones occur most commonly in the pelvis. The nature of the condition of a number of the reported cases was unknown for 10 or more years. The lesion is slowly progressive, the bone is destroyed as the cysts increase in size, but the radiograph often shows bony septa—these may become detached and absorbed. Collections of calcium may be deposited in the cysts. *H. S. Stone* records a case of echinococcal involvement of the sacrum and ilium which gave rise to lumbo-sacral pain by pressure on the nerve trunks. At operation echinococcal cysts were recovered from the spinal canal. *Hsieh* recorded a case in a man of 48 who had noticed a swelling in the right thigh and buttock for 8 years which appeared to be rapidly increasing in size. The radiographs used to illustrate the article showed multilocular cystic destruction of the femur and one side of the pelvis—the bony periphery was dense and there were scattered septa within.

Fränkel and *Pytel* illustrate with photographs and radiographs a hydatid cyst which destroyed the left side of the pelvis of a woman of 27.

Ikselrad shows a large hydatid of the ilium of a woman of 38. In the case of a doctor 50 years of age illustrated by *Kienböck and Mayer* the cystic bone destruction involved the whole of one side of the pelvis, and the acetabulum was perforated by the head of the femur.

B. L. Coley illustrated complete destruction of the ilium in a man of 20 years of age, and a large cyst of the sacrum in a man of 58 years of age.

In one case seen by the author the cysts involved the sacro-iliac area, and the deformity seen in cases of spondylolisthesis resulted. Similar septa may be shown in plasmocytoma and hæmangio-endothelioma, but in these conditions the septa are usually more clearly defined and collections of calcium are rarely seen. Some secondary carcinomata produce a similar appearance.



FIG. 823. Type 2. Destruction of the ilium by secondary deposits of lympho-sarcoma. Primary in neck detected 2 years previously.

The radiographic appearance of multiple rounded areas of rarefaction about ¼ to ½ inch in diameter in a pelvis which shows general osteoporosis is usually due to multiple myelomatosis and examination of the urine for Bence Jones albumose is indicated.

Sarcomata of the bones of the pelvis are not infrequent in children. Radiographs often show very extensive involvement of the whole pelvis—the bone may be rarefied and its normal striation destroyed, or massive osteoplastic growth, or areas of complete destruction. A massive tumour is usually to be felt. Pseudo-cystic areas in the pelvis are also produced by secondary deposits of Lympho-sarcoma (see Fig. 823).

joint, the symphysis pubis, the ischio-pubic junction and the rims of the acetabula have been produced.

Tumours. Isolated **Exostoses** consisting of bony masses of the density and internal architecture of normal bone may project into the pelvis causing marked irregularity and narrowing of the pelvic canal

Chondromata growing from the pelvic brim of which little indication may be given by the radiograph have been known to narrow the pelvic canal and obstruct labour The radiographs may show a fan-like striation of the ilium surface bone irregularities,



FIG. 332. Solitary plasmocytoma of ilium.

erosions or projections with woolly extremities, or amorphous deposits of calcium. Though histologically these tumours appear benign they may invade the veins and be disseminated.

Simple Cysts of the pelvic bones are rare they are occasionally associated with parathyroid tumours but **Multilocular Cystic Changes** are seen which may be due to hydatid cysts hæmangio-endotheliomata polyostotic fibrous and polycystic dysplasias



Fig. 325. Type 1. Secondary carcinomatous erosion of the walls of the acetabulum and ischium. The patient had complained of sciatica for five weeks—primary discovered in the prostate three months later.



Fig. 326. Type 2. Secondary carcinoma of the innominate bone. Multiple areas of cancellous destruction have merged leaving only irregular bony septa.



Fig. 327. Type 3. Secondary carcinomatosis of the pelvis in a woman of 55. Primary in breast. In some cases these changes from the normal develop within 3–4 months.

Metastatic Carcinoma. The bones of the pelvis are amongst the first to show evidence of metastases. These are frequently discovered accidentally during the radiographic investigation of cases of lumbar and sciatic pain; the primary tumour may not be discovered during life.

So frequently is the pelvis involved in malignant disease that in obscure conditions of any other part the diagnosis may be facilitated by a radiograph of the pelvis.[19]

Before conducting operative procedures for the removal of carcinomata it is advisable to radiograph the pelvis and spine for evidence of secondary deposits even as one should radiograph the thorax before operative treatment of sarcomata. So frequently does secondary carcinoma produce in elderly persons the painful conditions described as lumbago or sciatica that a most careful search should be made to detect any change in the structure of the bone. This is most important where manipulative procedures are contemplated otherwise fracture will result.

Though the radiographic appearance of carcinoma of the pelvic bones varies considerably, the picture is usually very definite and conclusive. Four main types of change are seen:—

(1) Erosion of the surface. The bone appears to be in contact with some corrosive



Fig. 324. Type 1. Secondary carcinoma of the pelvis of a woman aged 48, showing erosion of the body of the ilium. Patient had complained of indefinite pain in this area for 4 years. Later there was a pulsating tumour—primary found in the thyroid.

fluid which gradually dissolves the bone. This type is more commonly seen in malignant thyroid deposits and some prostatic carcinomata (Figs. 324 and 325).

(2) Multiple areas of cancellous destruction. These may begin as small pseudocysts which merge by destruction of the intervening bone until large areas with scattered irregular bony septa appear. These are seen in metastases from breast, lung, kidney and stomach carcinomata (Figs. 322 and 326). The metastases from the uterus may show localised pseudocystic appearances with well-defined septa, suggesting plasmocytoma or hyperparathyroidism.

the sacrum and fifth lumbar vertebra before death. The involved bone may appear to have been resected, so complete is its destruction (see Fig 330)

Middledorpf in 1885 described a tumour growing on the anterior surface of the sacrum Tumours of this type usually tend to erode the bone though they possess a



Fig. 330A. Lesion in sacrum obscured by gas in colon.



Fig 330B. Same patient after clearing colon. Note ... destruction of right side of sacrum.

definite capsule They exert pressure upon the pelvic viscera Bladder involvement appears to be more frequent than rectal

Hundling described these ventral tumours of the sacrum In a series of 10- tumours which occurred in babies *0 of the infants were born dead 13 were premature, and - died during birth

(3) Multiple diffuse islands of denser bone involving the whole of the pelvis commonest in breast carcinoma (Fig 327) and prostatic carcinoma

(4) General diffuse increase in the density of the bone, producing an appearance which somewhat simulates osteitis deformans, and like the latter may contain areas of rarefaction (Fig 328) Seen in some forms of prostatic carcinoma early stages of such



FIG 328. Type 4. Secondary carcinoma of the innominate bone. The patient, a woman of 60, had complained of sciatica for seven weeks Note the diffuse sclerosis of the acetabular region and the decalcification of the bone in the region of the pubis and iliac crest The primary was not discovered.

bone metastases show as round areas of increased density these gradually expand and coalesce The periosteal border may take on a woolly appearance and fine detail radiographs may show this to be due to fine fibre like spicules, resembling the pile on plush. After the administration of X radiation or calcium and after orchidectomy lesions of types 1 and 2 may appear to consolidate or show the density of type 4

Tumours of the Sacrum. No bone in the body can be so extensively invaded, its structure destroyed and the lesion escape detection as the sacrum (see Figs. 329 A and B). This is due to the fact that so frequently the bone is camouflaged by gaseous and fæcal contents of the bowel and rectum, also the detail of the structure and position of the sacrum itself is intricate and varied, but insufficiently dense in such a bulky area to give much contrast The author published radiographs of a chordoma of the sacrum in a woman aged 20 years. In spite of X radiation the tumour progressively destroyed

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Fig 329 A. Lesion in sacrum obscured by gas in colon.



Fig 329 B Same patient after clearing colon Note sarcomatous destruction of right side of sacrum.

definite capsule. They exert pressure upon the pelvic viscera. Bladder involvement appears to be more frequent than rectal.

Hundling described these ventral tumours of the sacrum. In a series of 107 tumours which occurred in babies 30 of the infants were born dead, 13 were premature and 7 died during birth.

(3) Multiple diffuse islands of denser bone involving the whole of the pelvis commonest in breast carcinoma (Fig 327) and prostatic carcinoma

(4) General diffuse increase in the density of the bone, producing an appearance which somewhat simulates osteitis deformans, and, like the latter may contain areas of rarefaction (Fig 328) Seen in some forms of prostatic carcinoma, early stages of such



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anæsthesia His radiograph shows obliteration of the detail of the sacrum which reappeared following X ray therapy

Salmond showed a similar result of radiation of a tumour of the sacrum.

Fig 331 is a radiograph showing destruction of the sacrum by a hæmangio-endothelioma.

Glioma, neurofibroma, chondroma, osteo-chondroma, Ewing's tumour sarcoma and secondary carcinoma have also been seen.

Tumour of the Cauda Equina. These may be present yet little or no alteration can be detected on the radiograph. They may be suspected in patients suffering from severe constipation who have radiating pains as well as burning pains in the perineum.



Fig. 332. Old fracture of the os innominatum with perforation of the acetabulum 3 years previously A man [illegible] years of age Note the massive callus.

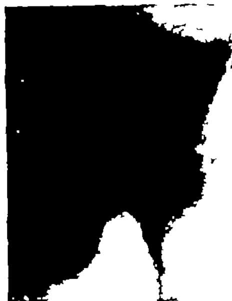


Fig 333. Radiograph of the left hip joint of a boy aged 18. It shows a perforation of the inner wall of the acetabulum by the head f the femur The patient f ll off a cycle

The patient may be free from pain while walking but recumbency usually brings on the pain.

Help in diagnosis can sometimes be obtained by injecting 1 cubic centimetre of lipiodol or other suitable radio-opaque oil into the cysterna.

Wolfsohn and *Morrissey* describe a case which was treated for 13 years as *Pott's* disease before the true nature of the lesion was discovered.

Deformities of the Pelvis due to Lesions in other Bones. Obliquity of the pelvis may be seen in cases of congenital abnormalities, injury or disease of the spine hip-joints and lower extremities, owing to the lesion bringing about an alteration of the mechanics whereby greater strain is placed on one side of the pelvis the structure of which develops compensatory moulding and sclerosis

Deformities due to Injury Fractures of the pelvis are frequently oblique a fracture

Hutton and *Young* described a sacro-coccygeal chondroma which destroyed the coccyx and lower part of the sacrum.



Fig. 330 Chordoma. Destruction of lower lumbar vertebræ and sacrum



Fig. 331 Antero-posterior radiograph showing decalcification of the sacrum due to a malignant hæmangio-endothelioma

M. *Béclère* described a pulsatile tumour of the sacrum, in a girl of 13 years of age, which was associated with incontinence of urine, paralysis of the rectal sphincter and

(1) Pregnancy leads to a relaxation of the pubic joint which is reflected in an increase in the gap between the pubic bones

(2) There is a great variation in the degree of this widening and in some cases it is so great as to be regarded as pathological

(3) It commences some time during the first half of pregnancy and in general does not progress after the last [illegible] months It is not increased by labour

(4) The width of the gap diminishes after labour

(5) In regard to the sacro-iliac joint there is some evidence of a similar change



FIG 334 Asymmetrical pelvis due to separation and unequal displacement at the symphysis pubis during pregnancy Though the antero-posterior radiograph does not suggest engagement of the fœtal head in the maternal pelvic brim, the lateral radiograph showed definite indentation of the fœtal head by the sacral promontory A radiograph taken a few days after a normal uneventful delivery showed that the bones of the pelvis had assumed their normal position

The efficiency of the pelvic apparatus is gravely jeopardised by any rocking movement between the sacral and innominate bone or between the two innominate elements The severe symptoms are sudden pelvic girdle pain and difficulty of walking or standing and a waddling gait with tenderness over the symphysis or sacro-iliac joint. Pain may be so great that the patient has to be kept in bed It may be brought on by the use of the bed pan

Young recommends rest, massage and immobilisation of the pelvis with a strap or belt. Any displacement at the pubic joint, whether widening or gliding is correlated with and is dependent upon the degree of movement at the sacro-iliac joint on one or both sides. The importance and significance of this was seen in a case investigated by the author Radiographs of a woman aged 38 showed the triangular area of increased density in the ilium abutting on the sacro-iliac joint on both sides (see Fig 338A) in associa

of the ilium on one side being associated with a fracture of the pubis and ischium on the other

They are sometimes associated with injury to the bladder or urethra, and it is probably due to the possibility of such injuries existing or likely to arise from manipulation that the fragments are usually allowed to fuse in the displaced position. In spite of the resultant pelvic deformity which can be demonstrated by radiographs, the patient shows a surprising ability in carrying out average exercises and duties.

Perforation of the pelvic wall of the acetabulum by the head of the femur has been seen in a number of cases In some cases the damage has not been apparent for several weeks after the injury when the bone has yielded to the pressure of the femoral head, and radiographs reveal an appearance of protrusio acetabuli—the roof of the affected acetabulum protruding into the true pelvis In other cases, as in Figs 332 and 333, the inward projection has been checked only by the trochanters meeting the brim of the acetabulum. Fractures are usually consolidated in massive and dense bone.

Cases have been seen by the author in which marked obliquity of the pelvic brim has resulted from a fracture of the pelvis with separation of one sacro-iliac joint and its early fusion (see Fig 330).

Avulsion of the anterior superior spine may result from sudden unguarded movement

DEFORMITIES OF THE PELVIS IN PREGNANCY

The anatomical variations in the form of the female pelvis have been well illustrated and described by *Caldwell Moloy* and *Swenson* (see also p. 321)

Any of the deformities of the pelvis which have been described may seriously affect labour and place the lives of the mother and fœtus in danger Some of the deformities may be suspected from the clinical examination of the patient and measurement of the pelvis, but additional help can generally be afforded by radiography

Radiography provides the best method of accurate measurement of the pelvic canal the lateral radiograph being the most important

To obtain suitable radiographs for this purpose, the patient is seated on the Potter Bucky Diaphragm in such a position that the brim of the pelvis is parallel with the radiographic film and the X ray tube placed at 4 to 6 feet distant to reduce projection distortion to the minimum.

Measurements are made from the films with a gauge previously prepared and adjusted to the height of the pelvic brim above the film.

For further details of the technique the papers by *Rowden Thoms* and others should be consulted.

Lateral radiographs should also be taken to show the shape and position of the sacrum and coccyx. Reference has been made in another chapter to the rectangular deformity of the sacrum, which may be the only indication of a pre-existent rickets

The terms pubo-sacro-iliac arthropathy or gestational arthropathy have been applied to the widening and displacement which occurs at these sites during pregnancy *Heyman* and *Lundquist* are of the opinion that the widening progressively takes place as the result of hormonal influences during the sixth and seventh months of pregnancy and not during labour or within the last 2 weeks of pregnancy The softening permits of a certain amount of movement and displacement. This may be unequal in the two sides and radiographs may suggest a permanent deformity of the pelvis but as in the case shown in Fig 334 return to normal occurs after parturition The condition has been investigated by *James Young* who summarises as follows :

Hofer investigated 139 male and 70 female Hollanders, and found the sulcus present in the ilium in 23 per cent. of men and 87 1 per cent. of women, and in the sacrum in 1 4 per cent. of men and 14 2 per cent. of women. From an examination of the radiographs of several thousand pelves the author considers that a much smaller percentage of English people have the sulcus developed to the degree shown on a radiograph (Fig 335). It appears to show greater development in women who have borne children In the adolescent it may be represented as a crescentic excavation of the surface less than ½ inch across but in the multipara it tends to assume the size shape and characters shown in Fig 335

Sacro-iliac Displacements. Displacement is a very common clinical but a rare radiographic finding very few examples have been discovered even after very severe



Fig 336. Asymmetrical pelvis due to a vertical fracture through the right side of the sacrum with separation and fracture at the symphysis pubis. Note that the sacro-iliac joints do not show any displacement even with this degree of trauma

trauma in the acute stage, but after several months dense reactive bone may be shown on the iliac aspect of the joint.

In one case (see Fig 336) the trauma sheared the sacrum vertically but left the sacro-iliac joints apparently intact.

Displacement at the sacro-iliac joint on one side associated with fractures of the pelvic bones has resulted in early fusion of the affected joint and a consequent marked obliquity and narrowing of the pelvic brim; a deformity resembling that seen in the *Nægele* pelvis. It may result in serious obstruction to the passage of the fœtus.

tion with osteoarthritic changes in the symphysis pubis. Her mother showed similar reactive changes in these sites

THE SACRO-ILIAC JOINT

The sacro-iliac joint is oblique, the large auricular surface of the sacrum, facing outwards and backwards, opposes a similar surface on the ilium which faces forwards and inwards.

Therefore on the antero-posterior radiograph the lateral borders of the sacrum overlap, and the medial borders of the ilia and the joint space cannot be seen. In some cases the opposing borders of the ilium and sacrum, instead of showing the usual convexity appear to be straight. In such cases a joint space can be seen

Congenital abnormalities are common and usually take the form of variations in the *lateral mass of the upper sacral vertebræ. An interesting defect of this nature produces* the deformity described by *Nägele* (see p 322) The first sacral vertebra may show bilateral or unilateral lumbarisation. The freed segment, instead of possessing the



FIG. 335 Radiograph of the female pelvis showing large pre-auricular sulci (sulcus paraglenoidalis).

normal sacral characters may be indistinguishable in its shape on the radiographs from the fifth lumbar vertebra Unilateral anomalies associated with these transitional vertebræ frequently lead to scoliosis and the early development of chronic arthritic changes owing to their defective mechanical structure Lumbarisation is frequently associated with failure of fusion of the laminæ and diminution of the disc space. Near the lower margin of the sacro-iliac joint, more commonly on the iliac side, but occasionally on the sacrum may be seen a crescentic excavation, the pre-auricular sulcus or the sulcus paraglenoidalis, *the sharp periphery of which has been wrongly* interpreted as evidence of early arthritic changes. In some cases the inferior margins of this sulcus nearly meet to form a round foramen. This is not a pathological condition *but a bony sulcus for the ligamenta sacro-iliaca anteriora* It is more frequent and larger in the female (see Fig 335).

joints of the vertebral column and that it is usually affected when the lumbar joints are involved in an acute arthritis, there is no definite evidence that the infection begins in the joint. It is no unusual thing to see arthritic changes in the lumbo-sacral joints while the sacro-iliac joints appear to be free In the author's experience lumbo-sacral arthritis is more frequent than sacro-iliac arthritis

Septic pneumococcal or any other infective arthritis of one sacro-iliac joint in a young person may result in early fusion of the bones and the development of a marked obliquity and narrowing of the pelvic brim and canal a deformity which presents radiographic features resembling those seen in the *Nägele* pelvis.

Unilateral or bilateral sacro-iliac osteoarthritis is indicated by irregular sclerosis of the subarticular bone, with the presence, in some cases, of similar cyst like changes to those seen in osteoarthritis of the hip joint. With incomplete lumbarisation of the first sacral vertebra, a mechanically defective joint is formed between the transverse process and the lateral mass of the sacrum or the medial surface of the ilium, and arthritic changes frequently develop and cause much discomfort.

What the author described in 1924 as a rare type of sacro-iliac arthritis is shown in Fig 338A. This patient a woman 40 years of age complained of pain in the lower part of the back. The radiograph shows a straight sacro-iliac joint on both sides with articular surfaces which appear to be almost in the sagittal instead of the normal, oblique plane There is a very dense and slightly expanded triangular segment forming the iliac side of the joint No change in the radiographic appearance or alleviation of the symptoms has appeared after prolonged trials of the orthodox treatments for arthritis Similar lesions have since been seen in women between the ages of 25–50 The name osteitis condensans ilii has been applied to it. Similar reaction has been seen by the author in the subarticular bone of the lumbar facets.



Fig. 338B Radiograph of pelvis showing teeth in a teratoma.

A number of cases have been seen in which the radiographs show some sclerosis of the inferior iliac segment of the joint, but in these there have been signs of osteoarthritis in the joint surface whereas in the case described the outline of the joints appears to be regular and the joint space of normal width

Arthritis. Arthritic changes in the sacro-iliac joints are common. In the adolescent, following exanthemata, evidence of arthritis may be discovered radiographically

It is perhaps the site in which ankylosing spondylitis is first recognised. In this



Fig. 537 Ankylosing spondylitis Early changes in sacro-iliac joints.

the margins of the joint lose their sharp contour and become woolly the joint space appears to be widened and the subarticular bone develops an increased density Later fusion of the bones occur and the joint space is obliterated This may be an isolated



Fig. 538A Uncommon form of sacro-iliac disease in a woman of 40. The patient has had persistent low back pain for several years. It has failed to respond to prolonged trials of orthodox treatments. Osteitis condensans ilii.

lesion or it may be associated at the time or later with similar changes in the lumbar facets or ossification of intervertebral ligaments.

Gilbert Scott gave his opinion that general ankylosing spondylitis frequently begins in the sacro-iliac joint. While it can be said to be one of the most commonly affected

CHAPTER XIV

THE SPINE

Radiographic Examination of the Painful Back. By far the majority of the patients referred to the X ray department because of painful backs show little or no evidence of departure from the normal to explain the cause of the pain: though enough, as will be seen from the following pages, show sufficient evidence to justify the examinations. A negative radiological report does not mean that there is no organic lesion. It may mean (a) that there are no changes in the bones or joints sufficiently developed at the time of the examination to show on the radiographs a change from the normal structure (b) that the examination has not been efficiently done, or (c) that the radiographs have not been accurately interpretated. It must be appreciated that organic disease of certain viscera produce symptoms, amongst the most prominent of which may be pain in the back. Such conditions as tuberculosis, gastric ulcer diverticulitis, various genito-urinary conditions, carcinoma and others are frequently associated with pain in the back and call for investigation. Another aspect of the problem is stated in the following trite passage from a paper by *Theodore A Willis* which may with advantage be quoted here "For the last 10 years I have been given opportunity to examine all spinal columns after students of the local medical school have finished their dissections I have found very little disturbance of these spines to indicate any curiosity on the part of the students as to even the gross anatomy of the part. This may explain the difficulties of the average physician when confronted with the problem of backache, as well as the tendency of the surgeon to turn his patient over and remove some of the dispensible parts from the abdomen or female pelvis, concerning the anatomy of which his curiosity has naturally been more active" There is another type of patient sent for X-ray examination of the back It is the patient who has complained of symptoms in one or other extremity which on clinical grounds is sufficiently normal to suggest that the cause is more centrally placed The following history emphasises the importance of adequate clinical examination before submitting the patient to radiographic examination. A patient complaining of intermittent pain in the back and thigh was sent for radiographic examination of the spine and as this was reported negative a report of the skull was requested with a similar result. This was followed by extensive histological and bacteriological examinations of his spinal fluid, blood, sinuses, etc. Later still a lipiodol investigation of the spinal canal was carried out. From all of these no material contribution was made as to the cause of the pain. A week after the investigation was ended the patient's practitioner sent him for a radiographic examination of the thigh and thus revealed an osteomyelitis of the femur—the site of his worst pain.

In a number of cases with persistent severe pain in the back, while on the first series of radiographs the spine appeared to be normal, subsequent radiographs 2 or more years afterwards showed slowly progressive ossification of the ligamentous insertions into the vertebral bodies. In a number of the patients manipulation had proved unsatisfactory and compared with some, who had been treated more conservatively appeared to show more extensive ligamentous ossification.

Radiographic Technique. Generally speaking the preliminary examination should include antero-posterior and lateral radiographs of the painful area. These should be of good quality preferably such as can be obtained with a rotating anode tube used in conjunction with a Potter Bucky diaphragm of a patient who keeps perfectly still

This type of reaction may be uni or bilateral; the former is often associated with old standing damage to the contralateral hip joint and appears to be a reaction to prolonged abnormal strain. As a bilateral lesion it has been seen in patients treated in early life for bilateral congenital dislocation of the hip-joints

THE COCCYX

The coccyx consists of four bodies which fuse with one another and sometimes with the sacrum at a variable age—the average being 20 to 25 years.

Radiography of the coccyx is undertaken in cases of coccygodynia, a condition which may or may not be associated with trauma.

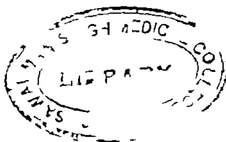
Deformities of the coccyx such as acute flexion on the sacrum or lateral displacement have been noted incidentally during radiographic examination for other lesions.

Sacro-coccygeal teratomata may be indicated on the radiograph by the presence of abnormal limb bones, bone fragments or teeth (see Fig 338 B).

Luccioni has described an anterior sacro-coccygeal teratoma which simulated a vesical calculus. The radiograph shows a fragment of bone with five teeth.

In those teratomata in which there are no calcium deposits the radiographic findings are negative, though a tumour is present.

B Sabat has described an intrarectal radiographic method for the coccyx. By this method excellent radiographs of the coccyx can be obtained. He illustrates numerous irregularities in its form and composition such as separate elements, fusion of all or between two adjacent segments, unilateral or bifid development, lateral horns to the superior surface of the first coccygeal body displacement of segments and arthritic changes in the sacro-coccygeal joint.



in the sacrum, the structures of which are often camouflaged by gaseous or fæcal contents of the colon (see Figs 379 A and B). Slight changes may be the only indication of a very serious lesion and its detection would save the patient and the clinician the distress occasioned by operative procedures

Details of this and other cases, illustrating the value of the lateral radiograph, I published in 1926 [2 and 3] and 1927

Care must be taken to maintain the true lateral perspective or radiographs liable to misinterpretation may result.

Kleinhaus has illustrated the appearance of apparent dislocation of the second cervical vertebra due to rotation of the neck As with the antero-posterior the lateral radiograph of the area under investigation should be taken with th central ray parallel to the superior or inferior surfaces of the vertebral bodies to avoid obscurity by the overlapping of other shadows. Additional help may be obtained by radiographs taken in oblique planes or stereoscopically but the necessity for these is indicated by a study of the individual, and the antero-posterior and lateral radiographs previously obtained.

Anatomical Considerations. In the fœtus the thoracic and sacral curves only are present in the spinal column, but as the child assumes the erect posture two secondary curves develop—the cervical and the lumbar Normally until puberty when standing erect these primary and secondary curves pass almost imperceptibly into one another preserving the balance of the trunk by concavity alternating with convexity The forward lumbar curve, which is more pronounced in the female than the male begins at the middle of the last thoracic vertebra and ends at the anterior surface of the lumbo-sacral joint. The latter point, which in the erect posture is said to be vertically under the occipital condyles, marks the commencement of the sacral concavity —a concavity which faces downward and forward, and extends to the tip of the coccyx

As adult stature is reached, the constant pressure of the weight of the trunk increases the sharpness of the lumbo-sacral angle

This weight is borne by the opposing surfaces of the vertebral bodies and their intervertebral discs anteriorly and to a lesser extent by the articular processes posteriorly In the healthy adult with a normally developed spine the curvatures are such as allow these surfaces to take the bulk of the downward pressure and the erect posture is maintained by the *tone* of the musculature without strain being placed upon the muscles and ligaments of the vertebral column.



FIG. 239 Achondroplasia. Infant showing characteristic dorso-lumbar curvature

If owing to ill-health, the tone of the musculature is diminished the weight causes an exaggeration of the normal curvatures and throws a strain upon the ligaments and articular surfaces. This is, of course most marked at the lowest part of the trunk where the flexible upper part articulates with the rigid extremity *i.e.*, the lumbo-sacral

during the exposure. Immobilisation of the part with a band may secure sharpness of detail which might be lost without. If these radiographs suggest any abnormality further radiographs of the suspicious area should be taken *preferably with the aid of a* cone to localise the radiation to a small area. Radiographs with the central ray obliquely directed may be indicated as essential for demonstrating the suspicious area, such as the articular facets. In cases of difficulty the clinician should explain the particular features to the radiologist who might then be able to position the patient so that additional evidence is secured.

Additional points have to be considered in those cases in which the spinal canal is examined after the injection of some foreign matter whether it be a radio-transparent gas or a radio-opaque liquid. Some authorities advocate air or oxygen, because it shows up the whole area of the canal under suspicion, but, except with the best technique, the outline of the air content is not easily defined and its behaviour cannot be watched *during movements of the patient under the screen. The majority of workers favour* lipiodol. Two or 3 c.c. of this are injected into the lumbar canal between the second and third lumbar vertebræ and the patient is then screened on a tilting table while being erected, inverted or rotated. Lateral bending of the patient towards or away from the side of the painful extremity may release a column of lipiodol which is held up in the straight position. The temptation to prolong the screening in order to watch the movements of the lipiodol should be checked, particularly if repeated examinations are made, because of the dangers of the cumulative effect of the radiation. The injection of 10 c.c. of thorotrast as an opaque fluid medium for investigating the spinal canal has recently been revived. Its use was discontinued because its radioactive properties were said to carry a carcinogenic danger. Attempts to secure freedom from the latter have been *made by washing out the thorotrast after the examination.*

B. H. Nichols claims to have used this method in more than 200 patients and found it accurate in diagnosis and localisation. The method visualises the whole canal and radiographs can be taken in antero-posterior, postero-lateral and oblique positions.

The author would stress the importance of making an efficient radiographic examination of the spine and having expert interpretation of the radiographs before any investigation is made with the use of injected materials which might mask important features.

It should also be kept in mind that most developmental irregularities of the spine and protrusions of the discs are present without being the cause of symptoms, therefore the discovery of these should not limit the examination unless they have some features *which indicate that they alone could be the causal factor.*

Interpretation of the Radiographs. The radiographs must be systematically examined, using a routine until it is automatic. This may take the form of a general survey during which

(1) The alignment of the vertebræ is noted.

(2) The outlines and internal structure of (*a*) transverse processes, (*b*) the vertebral extremities of the ribs, (*c*) the bodies, (*d*) the spinous processes, (*e*) the pedicles, (*f*) the articulations, (*g*) the discs.

(3) Changes in the ligaments and the adjacent soft tissue structures.

Failure to do this routine examination may well result in failure to detect an important lesion. The discovery of a lesion or suspicious area may indicate the necessity *for further radiographs to secure additional evidence.*

In stressing the need for careful examination of the detail of the structure I would point out that small areas of localised decalcification or breaking down of cancellous structure which do not alter the outline of the parts can easily be missed, particularly

The seventh cervical vertebra shows a separate centre for each costal process; these appear about the sixth fœtal month and unite with the main vertebra about the sixth year

The lumbar vertebræ have an additional centre for each process and there is radiographic evidence of additional centres for the tips of the inferior articular processes

Any one or more of these additional centres may fail to fuse.

The ossification of the sacrum has been referred to in a previous chapter

THE SHAPE OF THE VERTEBRAL BODIES

The lateral radiograph at birth shows that ossification of the vertebral bodies is

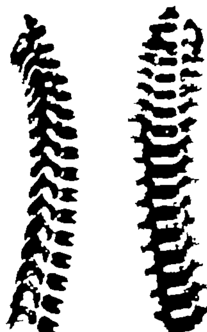


FIG 340 Antero-posterior and lateral radiographs of the spine of a fulltime fœtus Note that each side of the arch is separate fusion between its fellow on the opposite side or with the body not having taken place

more complete in the upper and lower thirds, the middle third showing only a narrow central isthmus of bone They appear as separate bobbin-shaped bones (see Fig 340)

On the antero-posterior radiograph two holes (venous channels) are shown in the middle segment, one on each side of the central bony septum. Radiographs taken a few weeks afterwards show that ossification of the posterior surface has been completed the body showing now an anterior notch only In some cases the bony lip above the notch may fail to develop or ossify in which case the body on lateral projection may be of slipper form (see Fig 3—) one or two bodies at the dorso-lumbar junction may appear smaller than adjacent bodies. These features are accentuated in chondro-osteo-dystrophy This anterior notch may be filled in during the first or second years, but in some cases it persists until the fourth or fifth year and even to adult life This appearance of a cleft through the middle of the bodies in the adult spine has been mistaken for fracture Fig 341 suggests that ossification of the anterior segment is more advanced in the

joint. Similarly if the bony structures of these areas have a congenital weakness, or their strength be diminished by any pathological process, the superincumbent weight will produce deformities of a nature dependent upon the position and extent of the weakness or lesion

In Achondroplastic infants the spine shows an unusual and characteristic posterior curve in the dorso-lumbar area (see Fig 380) The same curvature but less clearly defined, because of the irregularity in size and shape of the vertebral bodies is seen in severe degrees of chondro-osteo-dystrophy A more exaggerated curvature at this site occurs in some cases of spina bifida

OSSIFICATION

The vertebræ are ossified from three primary centres one for the body and one on each side for the neural arch and its processes. The two centres for the neural arches of the upper cervical vertebræ are the first to appear They can be demonstrated by the anatomist after the seventh week of fœtal life About a week after the centres for the upper cervical arches have appeared, osseous nuclei are to be seen in the lower thoracic bodies.

With each succeeding day further nuclei for the other arches and bodies appear the process of ossification spreading distally in the case of the arches, but proximally and distally in the case of the bodies the proximal progression of the latter being greater than the distal progression.

At birth (see Figs. 2 and 3) all the vertebræ except the coccyx are represented by a large central nucleus for each body and one on each side, but on a posterior plane, rather less in size, for the arch. No union between them can be demonstrated, but during the first year of life the lateral nuclei meet posteriorly and fuse—fusion taking place earliest in the lumbar region and progressing through the dorsal to the cervical vertebræ.

During the third year of life the completed neural arches begin to unite with the bodies, but in this case the process is initiated by the upper cervical and spreads distally —the lower lumbar not uniting until about the sixth year

Soon after puberty is attained secondary centres appear for the superior and inferior rims of each vertebral body the extremities of each spinous process (two for the bifid cervical processes) and the extremity of each transverse process. These additional nuclei normally fuse with the vertebral body or its processes about 25 years of age.

The epiphysis for the extremity of the transverse process of the first dorsal vertebra on one or both sides may fail to fuse and present an appearance which may be mistaken for fracture. *A Mayoral* cites a case in which compensation wa sought.

The times of appearance of osseous nuclei the rapidity of their growth, and the subsequent fusion of secondary with primary centres are subject to the same influences which retard or increase the rate of ossification in other parts of the skeleton Thus, in a case of hypothyroidism, a boy aged 6, one saw that none of the laminæ of the spine had yet fused Certain exceptions to this general scheme of ossification are seen in particular vertebræ. The atlas is ossified from three centres two for the posterior arch appear about the seventh week of fœtal life, and one for the anterior arch about the end of the first year of life. Fusion of the posterior arch occurs during the third year but fusion with the anterior arch does not occur until about the sixth year

The axis is ossified from five primary centres, one for the body at the seventh to eighth week two for the arch during the fourth month and two laterally placed for the odontoid process during the sixth month Additional centres for the tip of the odontoid appear about the second year and the inferior surface of the body about puberty

Hansen has illustrated the radiographic appearances of the spine from late fœtal life to the age of 14 years. He records the presence of vertebral epiphyses as early as the sixth year and the presence of the central "canal" in a patient as old as 32 years.

In the author's series there is a radiograph of the spine of a girl aged 4 years which shows epiphyses for all the dorsal vertebræ. These epiphyses appear early in osteogenesis imperfecta.

MOVEMENTS OF THE SPINE

The spine as a whole is capable of a wide range of movement, extension, flexion, and rotation.

In the course of the preparation of a film showing an investigation of the movements of the vertebral column by radiograph and cinema, by *Lockhart Fowler* and *Brailsford*, published in the Kodak Medical Film Library Anatomical Section, No 288, Female Acrobats, Part 3 two reels, it was determined that extension of the spine is greater than flexion, and that the greatest range of movement takes place in the lumbar area, the

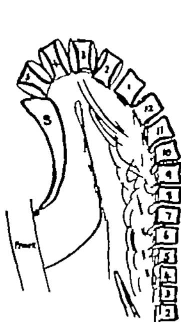


Fig. 342. Tracing of radiograph of the spine in extreme extension. The patient was radiographed with the spine bent backward and the head between the thighs. Note that most of the extension is in the lumbar area and that even with this degree of extension there still remains a slight kyphosis of the dorsal spine

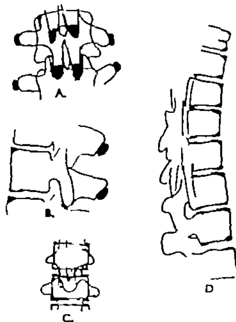


Fig. 343.

A. Ununited epiphyses of the transverse processes and the inferior articular processes.

B. Ununited epiphyses of the spinous processes and superior rim of the vertebral bodies.

C. Epiphyses for the superior and inferior rims of the vertebral bodies.

D Epiphyses for the superior and inferior rims of the vert bræ.

least in the dorsal. This was demonstrated in a girl who was able to bend backwards and place her head between her thighs. A lateral radiograph (see Fig 342) was taken of her spine in this position and it showed the dorsal spine parallel with the sacrum.

Even with this degree of extension, however a slight kyphosis of the dorsal spine persists.

upper lumbar area as it is completely ossified in the first lumbar and bridged across by ossification of the anterior surface in the second lumbar. The outline of the anterior surface shows a further alteration about the fifth to eighth year. During these ages the lateral radiograph shows a rectangular projection as a tongue of bone from the middle segment. This form may be seen earlier in the dystrophies. Examination of a macerated specimen of such a vertebra reveals a middle segment with a smooth anterior



Fig. 341A. Lateral radiograph of the *lumbar and lower dorsal spine of a* child 1 year of age. The dorsal and lower lumbar bodies show marked irregularity of ossification in the mid anterior segment. This area appears to be bridged across in the third lumbar and completely consolidated in the second lumbar.



Fig. 341B. Radiograph showing tongue-like projection of the anterior surface of the middle third of the vertebral bodies. Ossification in the epiphyses has not commenced.

surface which projects beyond markedly grooved upper and lower segments. These deep grooves pass from the periphery to the middle of the upper and lower surfaces. In the cartilage covering these grooves the ossified nuclei for the epiphyseal plates of the vertebra develop, so that on the lateral radiograph of the spine of a patient 10 to 18 years of age, shadows of these nuclei will be seen in the notches above and below the projecting middle third, the shape of the epiphyses varying with the angle of projection. In some children there is delay in ossification of the upper and lower segments so the middle segment of the bodies projects forward as a tongue (see Fig. 341 B). Later irregular ossicles may be seen in the upper and lower angles of the tongue.

small nuclei within the rectangular notches at the superior and inferior margins of the bodies. These persistent epiphyses for the vertebral bodies were first described in 1920 by *Hansen* in a woman aged 45 In the adult dorsal spine small triangular calcifications develop at the anterior border of the intervertebral discs. These are not epiphyses but degenerative foci and usually associated with slight pouting of the adjacent vertebral borders.

Several other workers, notably *Michalow* and *Tscherepnina*, *Hansen*[4] *Schmorl*, *Hellmer* *Jenker* *Junghanns*[1] *Joisten*, *Reisner*[1] *Lyon*[4] and *Marum* and *Looser* have published articles containing excellent illustrations of these epiphyses.

Rendich and *Westing* have drawn attention to the persistent epiphyses or accessory inferior articular processes of the lumbar vertebræ.

Groberger examined 200 subjects between the ages of 10 and 20 and found that the secondary epiphyseal centres in the transverse processes of the thoracic vertebræ generally make their appearance when the individual is between 11 and 14 years of age, and that the fusion is complete between 18 and 20 years. In some cases he had observed that the secondary epiphyseal centre in the transverse processes of the first thoracic vertebra continued to exist. In 3,000 cases over 20 years of age it persisted in 22 cases—bilateral in 7 on the right side in 9 and on the left in 6.

He points out that the appearance may be mistaken for that of a fracture.



FIG 315 Kyphosis in youth aged 18 with compression of vertebral bodies associated with chronic bronchitis.

Prior to the consolidation of epiphyses with diaphyses the bones appear to be susceptible to long continued strain. They can be compressed and their ossification can be seriously disturbed (see Fig. 315)

The Deformities of the Spine are due to —

(*a*) Congenital abnormalities; (*b*) Developmental irregularities (*c*) Injury (*d*) Habitual faulty posture (*e*) Pathological processes involving the bones, joints, ligaments, muscles and nerves of the part.

The degree of deformity depends on the nature and extent of the lesion. It reveals itself to the examining surgeon as a *faulty* posture or gait obliteration, exaggeration or reversion of the normal antero-posterior spinal curvature, the production of a lateral curvature, the presence of a tumour and the limitation of movements.

The same type of deformity may have a widely different ætiology and even after a thorough clinical and X ray *investigation* the true nature of the condition may not be determined

In stressing the fact that extension is greater than flexion, it must be remarked that leading anatomical texts are inaccurate upon this subject. The greater potentiality of the spine for extension than flexion is also a point of applied orthopædic importance. Further in the above investigation there is graphic illustration of lumbar rotation markedly exceeding the degree hitherto ascribed to the region.

PERSISTENT EPIPHYSES

Radiographs show that certain of the epiphyses or secondary centres of ossification of the vertebræ fail to unite with the parent bone (see Fig 343, A, B C) These epiphyses develop to their normal size and the metaphyseal unossified area which separates them from the complementary bony process becomes linear in appearance and may give the erroneous impression of a fracture. As the age of the patient advances, the more likely is the error to be committed, for not only have we the appearance of non-union, but also, on account of the defect in ossification, a false joint may develop and the signs of "arthritis," which may be thought to be traumatic in origin. Defects in ossification at whatever site appear in later life to be represented by osteophytic out growths, loose ossicles or calcified fragments and erosion. *They are usually referred to as* arthritis.



Fig 344 Lateral radiograph of the lumbar spine showing a persistent epiphysis of the *fourth* lumbar body and a smaller nucleus in a similar position on the third lumbar body A woman aged 46 years. No history of *injury* Chronic arthritic changes sometimes develop in these false metaphyseal joints and produce symptoms.

With the radiographic appearance of these persistent epiphyses anyone liable to be called upon to interpret radiographs should be familiar otherwise injustice or ignominy may follow (see Fig 344). Arthritic changes *sometimes develop in the metaphyseal joint.*

The possibility therefore, that the radiographic appearance of a detached bony fragment from the superior or inferior margin of the vertebral body the tip of the transverse spinous or articular process is due to a persistent epiphysis, should always be carefully considered *before stating that it is due to trauma.* The epiphyses for the superior and inferior surfaces of the vertebral bodies are thin plates of bone having a thicker compact peripheral margin and a very thin centre. Near the time of fusion to the vertebral body they appear as an ovoid ring of compact bone about $\frac{1}{16}$ inch thick and $\frac{1}{8}$ inch wide, with a thin cartilaginous centre. *This is in contradistinction to the lower animals. In the sheep, for instance* the epiphyseal plate is an entire flat disc of compact bone.

The radiographic appearance of these epiphyses is dependent upon the stage of ossification and the angle of projection.

On the true lateral radiograph these epiphyses appear as small triangular bony spicules on the upper and lower anterior margins of the vertebral bodies With slight obliquity the shadow of the epiphysis may be sickle-shaped The author has demonstrated them radiographically in a *girl aged 4 years They may first appear as*

Generally speaking it may be said that the most numerous departures from the normal are what may be termed transitional abnormalities, as they occur in the boundary vertebræ where one group meets another having different characters. Thus they are seen in the atlanto-occipital cervico-dorsal dorso-lumbar lumbo-sacral and sacro-coccygeal areas. In these areas the boundary vertebræ often develop, symmetrically or asymmetrically characters, more or less rudimentary of the vertebræ of the adjacent group. Any departure from the typical group architecture weakens or hinders the functional possibilities of the part the more so if these abnormalities are not concomitant with what might be called compensating abnormalities of the vascular and nervous systems.

If as is frequently the case, the bony abnormality is asymmetrical, the alignment of the vertebral column is deflected from the normal and this primary curvature has to be compensated by the development of secondary curvatures Such lateral curvatures



FIG 345. Radiograph of the lumbar spine showing a marked curvature due to congenital deformities of the third, fourth and fifth lumbar vertebræ.

cannot occur without rotation in the spine which has normally alternating forward and backward convexities As the lumbo-sacral region of the spine is called upon to withstand the super-incumbent weight of the trunk and head, deformity in this area will the more likely result in interference with the normal mechanics of the part and the consequent development of arthritic changes (see Fig 346).

For descriptive purposes the congenital abnormalities of the different groups of vertebræ will be classified into those affecting the vertebral body the articular processes the neural arch the spinous and the transverse processes.

The clinical examination may indicate the nature of the lesion, but the bone and joint changes may not be of sufficient magnitude to show on a radiograph sometimes a radiograph will show that the lesion is greater and more extensive than the clinical examination would lead us to suppose, and may throw much light on the ætiology

SCOLIOSIS

Scoliosis may be due to congenital deformities of the spine (particularly hemi vertebræ) or of the limb bones, habitual faulty posture occasioned by particular daily duties paralysis of spinal muscles or of an extremity defects of sight or hearing daily work necessitating the carrying of heavy weights, particularly in adolescence, injuries to the discs or vertebral bodies dystrophies of the skeleton, disease of the spinal ligaments, discs or vertebræ deformity or disease of the extremities, diseases of the lungs and other viscera.

The congenital deformities, and deformities due to disease of the discs and bone, are dealt with in chapters dealing with the specific lesions

R Lockhart has shown that the scoliosis which develops in school children from the habitual carrying of a hand bag is in marked contrast to the erect posture assumed by the child carrying a bag with bilateral shoulder-straps.

Postural scoliosis may show on the radiograph no other abnormality of the vertebræ than the curvature, but if the faulty posture continues the radiograph will show narrowing of the intervertebral spaces on the concave side of the curvature, sclerosis, and eventually lipping or even ankylosis of the approximated borders of the vertebral bodies *The radiographs therefore suggest that such cases of spinal curvature can be* classified into three groups Group 1 scoliosis with no bone changes Group 2, scoliosis with bone changes, first shown on the concave aspect of the curvature. Group 3, fixed scoliosis with marked bony changes, including obliteration of the intervertebral spaces, sclerosis and lipping of the approximated surfaces with ossification of the overlying intervertebral ligaments.

Schmorl has drawn attention to the injuries of the intervertebral discs produced by the carrying of heavy weights, particularly by young people.

Several cases have been seen by the author in which a severe scoliosis developed in the mid-dorsal area. The radiographs of these cases in the early stages gave one the impression that the curvature was due to the laxity of the intervertebral ligaments and muscles they showed no definite bone disease or deformity Further radiographs taken after an interval of 5 or 6 years, during which period medical treatment had not been sought showed a most striking scoliosis on the antero-posterior radiograph. The author *has illustrated*[11] *that marked plasticity had developed The vertebræ* had undergone structural adaptation to the altered position, and in one case the curvature was so marked that the upper border of the seventh dorsal vertebra appeared on a more proximal plane than the lower border of the fourth dorsal.

CONGENITAL DEFORMITIES

Congenital deformities of every degree of severity are met with. Some, incompatible with life, others, so trifling, that their presence would not be suspected except for radiographic examination or anatomical dissection

Of those which are compatible with life, the most severe are found in the lumbar and sacral spine

I have recorded the case of a boy in whom the lumbar and sacral vertebræ are represented by irregular masses of bone devoid of all the normal architecture. One case showed failure of ossification of the spine below the dorsal column.

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FIG. 344. Radiograph of the lumbar spine showing a marked curvature due to congenital deformities of the third fourth and fifth lumbar vertebræ

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CHAPTER XI

THE LUMBAR AND LUMBO-SACRAL REGIONS

The chief distinctive characters in the normal anatomy of the lumbo-sacral area should be appreciated when a radiographic examination of this area is made.

The fifth lumbar vertebra has several features which distinguish it from other lumbar vertebræ. Its body is slightly wedge-shaped, being deeper anteriorly than posteriorly.

Its transverse processes are continuous with the anterior surface of the vertebral body and, in relation to the body, lie on a more anterior plane than the transverse processes of the vertebræ above; they are usually shorter than the third lumbar transverse processes.

J. C. Brash points out that there is a gradual increase in the size of the transverse processes of the lumbar vertebræ from the first to the third, that the fourth are shorter and the fifth usually a little longer than those of the fourth, and that they point upwards, outwards and backwards.

Fawcett has illustrated the transverse processes of the fifth lumbar vertebra with two epiphyses—one for the costal element and one for the transverse element.

The spinous process is usually a little shorter, more pointed and not so deep as the spinous processes of the other lumbar vertebræ and its extremity is on practically the same plane as the inferior border of the vertebral body.

The pedicles are broader, being strengthened by the continuation of the transverse process into the body.

The superior articular surfaces are wider apart than those of the upper vertebræ.

The inferior processes are about as wide as the superior processes.

There is a great variation in the direction in which the articular surfaces face; in the majority of cases the superior facets face backwards and slightly inwards while the inferior facets face forwards and slightly outwards.

The intervertebral disc of the lumbo-sacral joint is also wedge-shaped, and is thicker anteriorly than posteriorly, thus making allowance for the lumbo-sacral angle.

The five sacral vertebræ have fused together into a triangular shaped mass; the costal elements are represented by the row of small tubercles on each side of the posterior surface. The spinous processes are smaller than those of the lumbar vertebræ. The laminæ of the lower vertebræ often fail to fuse and complete the neural arch.

The sacrum has a concave anterior face which looks forwards and downwards. Considerable variation is seen in the degree of concavity and direction. The superior articular surfaces usually face backwards and inwards, but these also show many variations.

The opposing surfaces of the fifth lumbar vertebra and the sacrum are joined together to form the lumbo-sacral joint by the following ligaments:—

(1) Intervertebral fibro-cartilage which also acts as a buffer between the vertebral bodies.

(2) Anterior longitudinal ligament which is attached to the intervertebral fibro-cartilage and the edges of the vertebral bodies—the fibres being of various lengths joining two, three or more vertebræ.

(3) Posterior longitudinal ligament attached to the posterior surfaces of the adjacent margins of the vertebral bodies. It is narrower opposite the bodies, and therefore has a dentate appearance.

G Okonek has shown in 15 cases that as the result of congenital kypho-scoliosis symptoms of compression of the cord may develop during the second decade of life.

Deformities of the spine of the intrauterine fœtus and the new-born babe are described in Chapter I.

The transverse process of the atlas sometimes has a separate nucleus for a posterior tubercle. With the development of this, the process has a bifid extremity The posterior tubercle may be elongated and articulate with the occiput posterior to the styloid process It may fail to fuse, either with the transverse process or the occiput and appear on A.P radiographs of the skull as a separate ossicle. The bifid process is *shown in the skeleton of an achondroplasiac dwarf in the Birmingham University* Anatomical Museum.

As recorded in the skeleton at birth (p. 2), the nucleus for the odontoid process is not ossified Apparently it may fail to develop for we see adult cases without an odontoid—they are usually discovered accidentally after injuries. The defect renders displacement more ready—fusion to adjacent vertebræ has been brought about surgically to consolidate the area.

The following anomalies were found in the lumbo-sacral area in the examination of 3 000 spines :—

Spina bifida occulta fifth lumbar 6 per cent
Spina bifida occulta first and second sacral, 11 per cent.
Sacralisation of fifth lumbar one side 3 4 per cent.
Sacralisation of fifth lumbar two sides, 4 7 per cent.
Hemivertebræ 3 per cent

These figures may be compared to those of other workers.

O Reilly who examined a large series of cases with anatomical variations, considers that 50 per cent of them showed symptoms of varying severity *Pugh*, on the other hand, states that 85 per cent of the backs which he has examined showed some deformity and he therefore concludes that the majority have no clinical significance.

Rick examined 300 cases of painful back, and found that 80 per cent. showed some deformity or malposition of the fifth lumbar vertebra.

THE VERTEBRAL BODY

The bodies of the vertebræ develop from one centre of ossification which appears about the fifteenth week. An epiphysis for the superior and inferior surface appears about puberty and unites with the main body at about the twenty-eighth year

Instead of a single centre for the vertebral body two lateral centres may develop and fail to fuse Between these hemivertebræ the meninges may protrude and a large meningocele may develop on the anterior surface of the vertebral column—anterior spina bifida.

Demel recorded an anterior sacral meningocele in a patient 20 years of age which was successfully removed

In other cases only one of the two lateral centres develops.

This may remain as a separate unit or it may fuse with the elements above or below but, whereas the split body does not give rise to any clinical deformity (it may be associated with an anterior spina bifida), as a rule, the lateral hemivertebra produces a lateral curvature We have seen that the normal spine forms a series of antero-posterior curves, but with this asymmetrical growth the mechanics of the balance of the erect posture will be altered, and a compensating lateral curvature must be formed.

This cannot occur without a rotation of the other vertebræ which was demonstrated by *Lovett* with a flexible straight rod which could be readily bent in either an antero-posterior or lateral direction, whereas a curved rod could only be bent in another plane if the rod underwent some rotation.

A number of examples of scoliosis due to the development of hemivertebræ occurred in the series (see Fig 347). In one, the radiograph shows the scoliotic deformity produced by a hemivertebra of the first sacral segment, and an irregular development of the left pedicle and inferior articular processes of the third lumbar vertebra, and the superior articular processes of the fourth lumbar vertebra, which give the appearance of a fracture of the fourth vertebral body

Dwight also mentions a case of an extra half segment in the sacrum.

J C Brash suggests that in the case of half vertebræ the bony condition is secondary to the nerve abnormality

There is a specimen (No 82°) in the Museum of the Royal College of Surgeons, of the lumbar spine and sacrum of a child aged 12 in which the fifth lumbar vertebra is represented by a right-sided hemivertebra, and the alæ of the first and second sacral vertebræ are poorly developed. This has caused a very marked angular curvature of the sacrum to the left, which is at right angles to the lumbar vertebræ The laminæ

(4) Articular ligaments and capsules

(5) Ligamenta flava, yellow elastic fibres which bind together the laminæ of the adjoining vertebræ and close the intervals between the laminæ the fibres extend laterally as far as the articular capsules medially they meet under cover of the root of the spinous processes.

(6) Interspinous ligaments composed of obliquely interlacing fibres passing between adjacent spinous processes from the tip of one to the base of the next.

(7) Supraspinous ligaments—from tip to tip of adjacent spinous processes.

(8) Lateral lumbo-sacral ligament which passes from the transverse process of the fifth lumbar vertebra to the base of the sacrum, expanding as it proceeds and some fibres becoming attached to the anterior sacro-iliac ligament.

(9) Ilio-lumbar ligament from the tip of the fifth lumbar transverse process to the iliac crest. Some fibres from the fourth lumbar transverse process blend with the fibres from the fifth. The ilio-lumbar band proper is a thickening of the ventral layer of the lumbar fascia.—(Quain's Anatomy)

The psoas muscle passes over the antero-lateral aspect of the lumbo-sacral joint. The posterior relations are the intertransversarii interspinales, multifidus, sacro-spinalis muscles and the lumbo-dorsal fascia The quadratus lumborum is attached to the transverse processes. The antero-lateral relations of the joint are the lumbo-sacral trunk, which comprises the whole of the anterior division of the fifth and a part of that of the fourth lumbar nerve it appears at the medial margin of the psoas major and descends over the pelvic brim and in front of the sacro-iliac joint to join the first sacral nerve.

The last lumbar nerve emerges between the upper sacral articular process and the back of the intervertebral disc, and its posterior primary division turns back round the process to reach the post vertebral muscles, while its anterior part runs forward, outward and downward on the ala, being joined here by the branch from the fourth. Thus the nerve appears to emerge through an osseo-fibrous foramen completed externally by arching fibres of the ilio-lumbar ligament All these structures are placed deep in the psoas (*Fraser*).

The common iliac arteries and their bifurcations, the iliac veins and the ureters are also closely related to the antero-lateral aspect of the joint, with the addition, on the left side, of the pelvic colon and mesocolon.

The fifth lumbar nerve passes through an oblique bony canal which is directed forwards and outwards and is bounded anteriorly by the postero-lateral surface of the body of the fifth lumbar vertebra, the posterior surface of the intervertebral disc and the posterior surface of the upper part of the sacrum laterally by the psoas muscle and some fibres of the ilio-lumbar ligament, posteriorly by the anterior surface of the articular processes

The importance of these joint relations to the nerve canal is emphasised in cases where these joints are involved in arthritic changes.

Bonlot and *Forestier* state that the fourth and fifth bony nerve canals are long the nerve funiculi are not protected by an anatomical arachnoid sheath, and are therefore influenced and irritated by variations in the rich venous plexus contained in the bony canal.

DEVELOPMENTAL ABNORMALITIES

The variations in the development of the elements of the lumbo-sacral region of the vertebral column are very numerous and I shall deal with their importance in producing deformity according to the position of the variation.

of the vertebræ from the third lumbar to the extremity of the sacrum have not fused and their extremities are wide apart indicating an extensive spina bifida as well.

This specimen is described in the *Trans Clin Soc.*, 1885 by *Parker* In some cases two vertebral bodies fuse together but as a rule, these are found out only by accident, when the spine is X rayed for some other condition.

An example of fusion of the third and fourth lumbar bodies in a child of 2 months was seen by the author

In the adult one has seen similar fusion without deformity as the result of inflammatory changes so that the congenital nature of the abnormality may not be readily determined

What appears on the radiograph as an almost shapeless mass, may develop instead of the normal lumbar vertebræ Reference has been made to a case in which the radiographs illustrate the abnormal ossification of the lumbar spine of a male child of nearly 5 years of age. The normal spine appears to cease at the first lumbar vertebræ, after which three or four bony masses devoid of the normal characters are seen with no



FIG 448. Tracings of radiographs showing variations and abnormalities of the articular facets of the lumbo-sacral area.

A. The articular facets on the left are vertical and practically in the sagittal plane. On the right the facets are in the coronal plane. Anomaly of articular tropism.
B. Bilateral oblique lumbo-sacral facets.
C. Bilateral flat facets in the coronal plane There is a curvature at the lumbo-sacral junction. The appearance suggests that the fifth lumbar has dropped on the right side and its transverse process has been brought into apposition with the superior border of the lateral mass of the sacrum.

attempt at neural arch formation The sacrum is represented by a small irregular structure between the iliac bones. The child shows a marked kyphosis of the lumbar area and deformities of the lower extremities including talipes and webbing of the knees and toes, which is associated with incontinence.

No external appearance of spina bifida was present.

Bowman quotes a case of a boy aged 6 without sacrum or coccyx. In one case seen by the author the lumbar vertebræ were also missing

J S Bouslog and *A Esserman* have published radiographs of a female negro aged 9 years which show a broad second lumbar vertebra with duplication of the third, fourth and fifth lumbar vertebræ and sacrum. The condition was symptomless.

Deformity of the vertebral bodies is seen in the osseous dystrophies (see Fig 377)

Articular Processes. The articular facets are developed from the ossification centres of the neural arch one on each side of the body

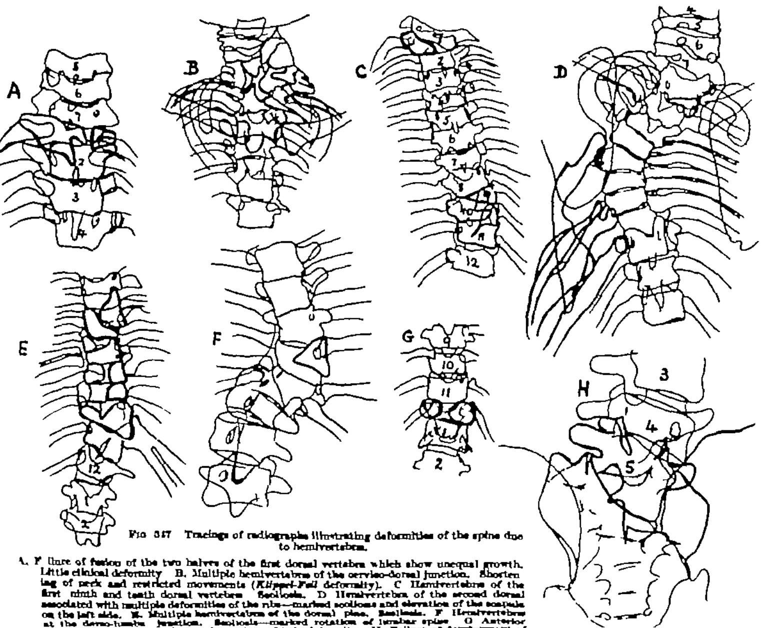


Fig. 317 Tracings of radiographs illustrating deformities of the spine due to hemivertebra.

A. Failure of fusion of the two halves of the first dorsal vertebra which show unequal growth. Little clinical deformity. B. Multiple hemivertebræ of the cervico-dorsal junction. Shortening of neck and restricted movements (*Klippel-Feil* deformity). C Hemivertebræ of the first, ninth and tenth dorsal vertebræ. Scoliosis. D Hemivertebra of the second dorsal associated with multiple deformities of the ribs—marked scoliosis and elevation of the scapula on the left side. E. Multiple hemivertebræ of the dorsal spine. Scoliosis. F Hemivertebra at the dorso-lumbar junction. Scoliosis—marked rotation of lumbar spine. G Anterior spina bifida of the twelfth dorsal vertebra. Little deformity. H. Failure of development of the right side of the first sacral vertebra resulting in marked scoliosis.

fuse with the body of the vertebra Reference has been made to the fact that this ossification may be considerably delayed in certain conditions such as hypothyroidism.

In the radiographs of the 3 000 patients examined, defects in the neural arch of the

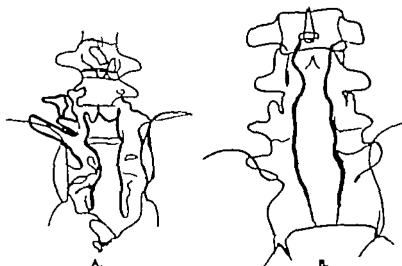


Fig 349

A. Spina bifida of the fifth lumbar and all sacral vertebræ with very abnormal transverse processes.
B Spina bifida of the fourth and fifth lumbar and sacral vertebræ.

fifth lumbar vertebra were shown in 6 per cent., and in the first and second sacral vertebræ in 11 per cent The degree of defect varied The patients presenting an obvious tumour associated with spina bifida were not radiographed as a rule (see Fig 340)



Fig 350

A. Failure of fusion of the laminæ of the fifth lumbar vertebra—spina bifida occulta
B Failure of fusion of the first sacral vertebra—ununited epiphysis of the spinous process.
C. Irregular ununited laminæ of the fifth lumbar vertebra wrongly interpreted as a fracture

In some the neural arches of the lumbo-sacral area were represented by small tubercles, but the majority showed only a split between the posterior extremities of both sides, one or other side having a bulbous extremity indicating that no bony union had occurred.

Rambaud and *Renault* are of the opinion that the arch has two primary centres on each side, and the two parts in each half are united by a plate of cartilage set obliquely between the superior and inferior articular processes. This may explain those examples of fifth lumbar vertebræ with a separate neural arch comprising the spinous process, laminæ, and the inferior articular processes which are united during life by synchondroses. A suggestion of this type of deformity may be obtained from the radiograph.

There is a specimen in the Royal College of Surgeons Museum which shows a well-developed neural arch, including thick laminæ and normal-sized inferior processes and spine of the fourth lumbar vertebra, as a separate unit, not fused with the remainder of the vertebra. Forward displacement of the upper column on the lower may occur with this defect. Progressive slipping has not been seen by the author at this site.

In a previous publication by the author [*] it was demonstrated that such non-fusion may exist, and yet the radiographs give no evidence. Radiography of such a specimen, after uniting the separate arch and body with soft radio-transparent wax, shows no evidence that the laminæ have failed to fuse, but shows though the two parts have failed to fuse, each is fully developed

The articular facets of the lumbo-sacral joints show great variation in their shape and the plane of the articular surfaces (see Fig 348).

The superior articular facets on the majority of sacrums are slightly crescentic, and face backwards and slightly inwards. If the greater part of the facet faces backwards, no idea of the condition of the surface of the joint can be obtained from a radiograph, but if the greater part faces inwards, then the joint surfaces with a narrow space between them can be seen on the radiograph, and any irregularity of the surface may be detected In some cases one facet faces backward and the other inward—what *Putti* describes as anomaly of articular tropism.

As a general rule, the surfaces are vertical, but this is not always the case. A careful examination of all the radiographs of more than 3 000 patients suggests that 57 per cent. face backward, 12 per cent. inward and 31 per cent. are mixed *i.e.*, one side may face backwards and the other inwards one may be vertical, the other oblique.

In some cases the surfaces are quite flat and face directly backward. This is said to be the rule in " native races.

Most authorities are agreed that, with asymmetrical development of the articular processes, abnormal movements occur Obviously the flat type gives stability in one plane only so that any force directed in another plane will strain the ligaments of the joint. Separation of the neural arch with the inferior articular processes may lead to a forward dislocation of the lumbar spine on the sacrum, spondylolisthesis.

Willis found a separate neural arch in 31 out of 748 cases which he examined in 23 it was bilateral, the right half was involved in every case Thirty were males, 1 female; 28 were white, 3 were negroes.

Von Lackum studied 30 bodies to determine if any anatomical instability was present in the lumbo-sacral area to account for the prevalence of low back pain. He found that in only 6 were the articulations of the lumbo-sacral joint symmetrical, 18 were grossly asymmetrical. In only 8 of the cases in my series was a clinical deformity explained solely by an abnormal development of the articular surfaces. In these cases the superior articular facets were small and irregular while the inferior facets and laminæ of the vertebræ above showed abnormal development, which resulted in scoliosis.

In the radiograph, of which Fig 348 C, is a line drawing the appearance suggests that the flat facets have permitted the right side to drop.

Defects in the Neural Arch. The centres of ossification for the neural arch are present at birth and fuse together during the first year and about the sixth year they

sphincters, but may be on occasion severe. Paralytic deformities and neurotrophic joints may develop.

Whitehead records a spina bifida in an adult female, which from birth to the age of 21 was associated with a meningocele about the size of an egg but with no symptoms. At this time the patient's circumstances compelled her to do hard manual labour and the tumour increased to the dimension of 22 inches in circumference. Concomitant with the increase in size the patient commenced to have severe headaches, nausea and vomiting attacks of vertigo and transient moments of defective vision whenever the tumour was subjected to pressure, even by the clothing

The tumour was aspirated, cauterised, and, after severe inflammatory changes, finally healed and the patient made a complete recovery

(5) Spina bifida occulta. This is the commonest type of spinal deformity seen. In this there is a failure in the development of the neural arch of several vertebræ—usually in the lumbo-sacral area. The only physical sign may be a small lipoma, or a tuft of hair or a dimple in the skin. There may be no symptoms, but some cases show progressive deformities of the lower limbs, talipes equinus, pes cavus, or instability of the lumbo-sacral region with low back pain or pain from pressure on the nerve trunks, neurotrophic joints of the lower limbs and disturbance of micturition.

Operative measures for removal of the cystic swelling or other abnormality may not influence the chief symptoms due to nerve abnormality which may be in the same developmental segment and consequently at a much higher level in the adult cord. These developmental errors are usually symmetrical, but some cases show definite asymmetry (see Figs. 349 and 350).

Fitzmaurice Kelly showed a case of a female child of 4 years 4 months in which the lateral mass of the sacrum and the fifth lumbar vertebra were missing and a cystic mass was situated under the gluteus maximus The child had severe paralytic talipes of both feet and incontinence of urine.

Roccia recorded the details of a patient who was without complaint until 17 years of age. At this age nocturnal enuresis appeared and was followed by retention which necessitated catheterisation. At the age of 25 years motor sensory and trophic disturbances appeared. A radiograph showed a spina bifida of the first lumbar vertebra. The patient died from ascending infection of the kidneys, and at post mortem a cholesteatoma was found involving the conus terminalis. The significance of the radiographic demonstration of spina bifida occulta in the treatment of a patient's symptoms is illustrated by the records of a number of cases that have been cured by surgical removal of the fibrous bands which develop in association with the skeletal anomalies.

Constantini, Bernasconi and *Coumot* record spina bifida occulta of the fifth lumbar and first sacral vertebræ in a child of 12 years who was incontinent. At operation the nerve canal was found to be constricted by fibrous bands These were resected, and three days afterwards normal micturition was established.

Stropeni, Francois, Lombard and *Largrot* record similar cases with successful surgical results

Reference has been made in the chapter dealing with the foot to the neurotrophic joints which sometimes develop as a result of the involvement of the nerves of the lower extremity in these cases of spina bifida occulta.

SPINOUS PROCESSES

The spinous processes are formed by fusion of the two sides of the laminæ which takes place in the first year and the development is completed by the growth of an epiphysis which appears about the sixteenth year and fuses with the main mass in the

This non-fusion of the laminæ often give an appearance suggestive of fracture indeed, several of the cases had previously been reported as fracture of the laminæ (see Fig 350).

Baetjer found a failure of fusion of the fifth lumbar vertebra in 15 per cent.

Wentworth found a failure of fusion of the fifth lumbar vertebra in 8·1 per cent.

Willis found a failure of fusion of the fifth lumbar vertebra in 79 of 1,500 skeletons, or rather more than 5 per cent. He described 7 types of defect some of which occurred singly whilst other cases showed several of the defects.

Decker describes a sixth lumbar vertebra with a spine split into two unequal portions and an articular surface between. The left portion is shorter 1 2 centimetres long, more or less pointed, and is attached to the lamina 1 5 centimetres broad, and with the lamina is directed backward and outward, so as to be slightly concave laterally The right portion embraces most of the spine is club-shaped, and is attached to the lamina 1 6 centimetres broad which is directed almost horizontally outward. Another defect in the neural arch occurs in the right pedicle just behind and below the superior articular process, where there is a narrow triangular articulation 2·8 centimetres by 0·6 centimetre, looking upwards and slightly forwards The separation of the pedicles is not complete, however for below this joint, between it and the inferior articular process there is definite bony continuity

The deformity described as Spondylolisthesis is also seen in association with defects in the neural arch. An example of anterior dislocation of the lumbar vertebræ at the lumbo-sacral joint, together with spina bifida of the lumbar vertebræ in a child of 2 years of age, was recorded in a [19] paper on Dislocations of the Lumbar Vertebræ.

SPINA BIFIDA

Five different types of spina bifida are met with —

(1) The myelocele, in which the central canal of the cord is exposed and the bony elements of the neural arch are represented by small nodules on each side of the posterior *surface of the body The author has shown* [21] *that this presents a characteristic* radiographic appearance which can be recognised in the fœtus in utero (see p 15)

This type is usually located in the dorso-lumbar area and is not compatible with life It may extend along the whole spine.

(2) *The syringo-myelocele, in which there is a dilatation of the* central canal with stunted development of the laminæ. In this type there is a tumour of variable size and cord symptoms are present paralysis of the lower extremities and incontinence.

(3) The meningo-myelocele, in which there is a dilatation of the meninges of the cord *through which the fibres of the cauda equina pass*

This is a very common type and is usually accompanied by paralysis of the lower extremities and incontinence, sometimes rigidity and contractions.

(4) The meningocele, which is a dilatation of the meninges and contains only the *cerebro-spinal fluid and no nerve elements*

The common site is the lumbo-sacral region of the spine. Ante-partum radiographs may fail to give any evidence of even large examples of types (3) and (4) in the fœtus.

Usually four or five of the neural arches are stunted (see Fig 349).

The cystic swelling may be as large as the child's head, or quite small. It may be tense or flaccid and the opening communicating between the cystic dilatation and the meninges may be very small.

This and the preceding types are often associated with hydrocephalus. Operative *measures applied to the cystic swelling may* be followed by the production of hydrocephalus

The symptoms may be slight, such as weakness of the lower extremities and

TRANSVERSE PROCESSES OF THE FIFTH LUMBAR VERTEBRA

There is no more variable part of the fifth lumbar vertebra than its transverse processes, and no part in which developmental asymmetry produces deformity in so many cases (see Fig 333) Bound up with the irregular development of these processes is the numerical variation of the vertebral column and sacralisation of the fifth lumbar or lumbarisation of the first sacral vertebræ. Numerous observers have studied this question. The normal formula—cervical 7 dorsal 12 lumbar 5 sacral 5 and coccyx 4—varies in about 20 per cent. of cases (*Quain*)

The cervical region is the most constant, but the most frequent site for the variation to be noticed is the lumbo-sacral This is due to the marked difference in the characters of the free lumbar vertebræ and the fixed consolidated sacral vertebræ. Attention is drawn to the variation in the cervical area by the cervical rib or its fibrous attachments pressing upon the brachial plexus or some of its elements or the vessels. In the lumbo-sacral area variation is a common occurrence—in my series 3 4 per cent. show sacral characters on one side and lumbar characters on the other The variation in this area appears to be more frequent in the direction of elongation rather than in shortening of the column, but the statistics of different observers show differences in this respect. It will be noticed, as a rule that when the change of character is noted at the junction of one series of vertebræ with another the next junction will show a change in the same direction—a sort of oscillation passing distally or proximally In the case recorded by *J C Brash* with the formula C6½ T13, L5 S5 C4 there was no evidence of the fifth lumbar vertebra having been derived from the sacrum. Failure of the first sacral segment to fuse with the other bodies may suggest a sixth lumbar vertebra. Six lumbar vertebræ is a common X ray finding (see Fig 352)

Bardeen after a study of reports of 1 059 specimens, including 75 of his own, found that numerical variations occur in about 16 per cent. of vertebral columns, of which 7 5 per cent. have compensated variations and 8·7 per cent. are uncompensated, equally divided between increase and decrease of segments. He says that there is no evidence that intercalation of a whole vertebra occurs

Side by side with these oscillations in the vertebral characters, variations are seen in the constitution of the lumbo-sacral plexus.

Eisler records concomitant variations in the plexus of 18 per cent. of the cases They occur within wide limits as shown by the following table of extreme cases—

	(1) Prefixed Variety	(2) Normal	Postfixed Variety
Nervus Furcalis	L3 and 4 (double)	L4	L5
Obturator	L1 2, 3	L2, 3 4	L2 3, 4 5
Femoral	T12 L1 2 3 4	L2 3, 4	L2 3 4 5
Tibial	L3 4 5 S1 2	L4 5 S1 2, 3	L5 S1 2 3 4
Common peroneal	L3, 4 5 S1	L4 5 S1 2	L5 S1 2 3

The transverse process is developed from the centre of ossification for the neural arch, but at the sixteenth year an epiphysis appears which fuses with the main process about the age of 25

We have seen that the costal rudiments of the fifth lumbar vertebra extend over the pedicles to the sides of the body whereas in the sacrum they enlarge and form the alæ on each side—the transverse processes being represented only by nodules on the posterior surface.

twenty fifth year In some cases, where the laminæ fail to fuse, the epiphysis for the spinous process remains as a separate bone and can be seen on many radiographs of the lumbo-sacral area (see Fig 350 B).

The spinous process of the fifth lumbar vertebra shows variation in shape, size and position Sometimes it is flattened out, drawn out, and instead of being shorter than the spinous process of the fourth, it may be longer as in the cases of spondylolisthesis. It may be united to one side of the neural arch only or it may be represented by the *posterior extremities of the laminæ which have come together but not fused.*

It may be exactly in the mid line or directed to one side.

If for any reason the lordosis of the lumbar spine is increased or the lumbo-sacral angle diminished, the spinous processes are approximated to one another until in some

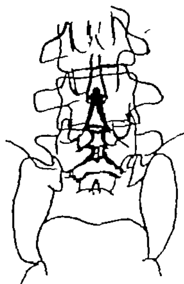


Fig. 351 Arthritic changes in abnormal joints between the spinous processes.



Fig. 352. Six typical lumbar vertebræ.

cases they touch each other and their opposing surfaces become moulded or faceted (see Fig 351).

The author * drew attention to the fact that, with such a spine extension is checked by the "locked-home" position of the spinous processes which are subjected to an abnormal strain, and bursitis and arthritic changes readily develop.

Such patients have pain in the back when standing erect, which is relieved by bending forward. This deformity developed during the 10 years which elapsed after the fracture dislocation shown in Fig 374 *Baastrup has well illustrated these lesions.*

A foramen has been observed by *Szawlowski* and *Dwight*, in the fifth lumbar transverse process which marks the costal from the true transverse element—the anterior part of the transverse process being the homologue of a rib, the true transverse element being represented by the posterior part of its root, including the accessory process.

When the transverse processes are large they may articulate with the sacrum—the lumbo-sacral transverse articulation of *Dwight*—but in some cases the processes grow out in a direct lateral line and articulate with the ilium.

Apart from the normal differences in the two sexes there are marked differences to be seen in the breadth of the sacrum and the height at which it articulates with the ilium. The transverse processes of the high sacrum are usually long and may be on the same plane as the iliac crests, whereas in the low sacrum, the fifth lumbar vertebra and even the fourth may be inferior to the plane of the iliac crest, and have only small transverse processes.

The high type of sacrum is much broader than the low The former is regarded by some authorities as unsound architecturally They argue that it is not so well supported by the sacro-iliac ligaments and spinal muscles. Radiographically the high sacrum appears a sound structure with the lumbo-sacral angle as a gentle curve extending over several vertebræ. Nevertheless spondylolisthesis has been seen in such spines.

The same condition is seen with complete symmetrical sacralisation of the fifth lumbar vertebra.

Moore is of the opinion that anatomically and architecturally the sacralised formation appears stronger and more able to resist strain than the usual arrangement.

Von Lackum suggests that surgical measures to fuse the fifth lumbar vertebra with the sacrum would be better than removing interfering masses.

While this is so with symmetrical sacralisation, with asymmetrical development of the lumbar processes, curvature and rotation of the lumbar vertebræ are produced, which in time are followed by compensating curvature of the dorsal vertebræ in the attempt to preserve the balance of the erect posture.

The vertebræ in their normal positions are so constructed that they can withstand the strain of normal movements and postures, but in the positions they occupy as the result of the curvature, they are placed at a disadvantage and cannot resist the strain placed upon them.

The curvature therefore tends to increase.

Aimes and *Jaques* in 63 cases of persistent lumbar pain, noted 38 instances of sacralisation of the fifth lumbar vertebra.

Basset describes a case of a girl of 23 whose pain was permanently cured by a partial removal of the long process of the fifth lumbar vertebra.

In my own series of cases 8·1 per cent. showed sacralisation of the fifth lumbar vertebra 3·4 per cent. being unilateral, 4 7 per cent. bilateral.

Many of these were discovered on the radiographs of patients complaining of symptoms suggestive of stone in the urinary tract for which they were X-rayed. There was no clinical evidence that the sacralisation produced symptoms. In some cases, however the patients complained of pain in the lumbo-sacral area, sometimes radiating down the back of the thigh, in which the only abnormality found was sacralisation of the fifth lumbar vertebra. In a few of these cases the patient had " sciatica " with some atrophy of the gluteal muscles on the same side as the sacralisation which had produced a scoliosis. There seemed to be some relation between the production of pain and the age at which articulation with the process occurred.

Owing to the frequency of these abnormalities in patients with no symptoms referable to this area, it is important to exclude all other possible causes before attri

A B C

D E F



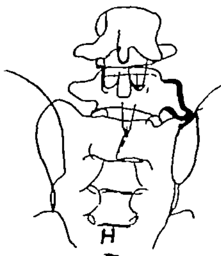


FIG. 358. Tracings of radiographs showing sacralisation or lumbarisation at the lumbo-sacral junction.

A. Bilateral sacralisation of the fifth lumbar in a child before the abnormal transverse processes have fused with the body of the vertebra. B. Bilateral sacralisation of the fifth lumbar. C. Unilateral broadening of the fifth lumbar transverse process. No articulation with the sacrum. D Bilateral sacralisation of the fifth lumbar On the right the transverse process has united with the superior border of the lateral mass of the sacrum. On the left the approximated surfaces of the transverse process and the sacrum are irregular and sclerosed indicating arthritic changes. E. Bilateral sacralisation of the fifth lumbar which has similar characters to the normal first sacral. The laminae have failed to fuse. F Asymmetrical bilateral lumbarisation of the first sacral. G. Unilateral sacralisation of the fifth lumbar in a child before the abnormal transverse process has united with the body of the vertebra. H. Unilateral sacralisation of the fifth lumbar Arthritic change commencing in the transverse lumbo-sacral joint.

symmetrical sacralisation of the fifth lumbar showed the widest angle. In these cases it can hardly be called an angle the lumbar vertebræ and intervertebral discs are so shaped that the forward curve is a gradual one and the change to the sacral concavity is spread over several vertebræ. The anterior surfaces of the last lumbar and upper sacral segments if produced make an angle which may be as great as 160 Commonly in the female the fifth lumbar body appears to be a little more wedge-shaped and its spinous process a little smaller to accommodate the greater sacral convexity

The body of the fifth lumbar vertebra and the lumbo-sacral intervertebral disc are thicker anteriorly than posteriorly as a result of which the weight of the trunk exerts a shearing strain at this joint and tends to diminish the angle The movements of stooping bending sitting and standing all call for lumbar movement; in fact, most of the principal movements of the trunk occur in the lumbar spine extension which is freer than forward or lateral flexion having a greater range here than in any other region.

Considerable discussion has been taking place on the subject of different muscle functions. It is held by some that there are two different muscle functions—that of postural tone and that of movement. The former controlled by the autonomic system should maintain the erect position without effort or fatigue. When postural tonus fails in its function owing to some general weakness, the other function of voluntary muscular contraction may be called in to take its place. This quickly leads to fatigue and pain. With this fatigue there is an exaggeration of the normal curves. The lumbar lordosis is increased and the intervertebral joints are maintained at the limit of their motion. This strain is usually felt by all patients after a prolonged rest in bed. A similar sequence of events is produced by regular employment which necessitates lifting or carrying heavy weights or assuming a bent position. Apparently as long as the individual is fit he periodically has a physiological reshuffle of his muscles, etc. and no damage accrues. But when, owing to fatigue or any disability he does not reshuffle, the strain is persistent and damage results. This may account for backache in patients following prolonged anæsthesia. See Fig 315

As a result of this long strain in the fully flexed or extended position, the bones undergo a degree of moulding and the ligaments are stretched until eventually the muscles cannot correct the deformity The balance, which in the normal subject is so well adjusted, is upset, and a gradual increase in the deformity results.

Goldthwaite distinguishes two well known variations from the normal skeleton which are particularly liable to be associated with lumbo-sacral backache

(*a*) The tall, slender visceroptopic type with a long, narrow flexible spine often assumes a faulty posture In this type the articular facets are flattened and movement is free. The lumbar lordosis is exaggerated and the lumbo-sacral angle is diminished. This results in approximation of the spinous processes to one another and adventitious bursæ are found between them. Constant slight traumata inflame the bursæ and they become a source of pain

(*b*) The short, thick, heavy type with diarthrodial facets large and crescentic. These limit the movements of the vertebræ, particularly lateral flexion. If the facets are unequal, the movements are irregular In this type the lumbo-sacral angle is strained.

Sudden unexpected blows directed to the trunk usually cause damage to the ligaments as the muscles are not on their guard and the joints are forced to the extreme limit of their excursion the ligaments controlling the extent of the movement are strained or even ruptured As the lumbo-sacral joint is the junction of the mobile and the fixed parts of the vertebral column, any such downward thrust on the upper part of the trunk or the momentum of a fall in which the patient lands on the buttocks will strain or rupture the ligaments of the joint. If the part be placed at rest until the liga

buting the pain to such an abnormality The importance of this is shown in the notes of the following case —

A patient, who complained of pain in the back had a radiograph of the lumbo-sacral region of the spine taken which showed asymmetrical sacralisation of the fifth lumbar vertebra, but a further radiograph taken of the vertebræ above showed destruction of the second lumbar body by secondary deposits of carcinoma.

In children, the large costal element of the fifth lumbar vertebra which is taking on sacral characters is often shown on the radiograph as a separate bone this suggests that it has a separate centre of ossification.

Gegenbaur has pointed out that the anterior part of the lateral masses of the first, second and third sacral vertebræ are developed from a separate centre which represents the costal element (*Fawcett*).

With unilateral sacralisation there may or may not be a scoliosis If the lumbo-sacral transverse articulation is painful the patient will list over to the opposite side and produce a scoliosis

In those cases in which the fifth lumbar transverse processes are long and articulate with the ilium, there may be no pain, but several cases which I have seen have complained of great pain over the articulation, and this has been the only bony abnormality to be seen on the X ray to account for it.

Verrall states that, in his experience, when symptoms do occur they consist of intractable pain, both local and referred to the area supplied by the fourth lumbar nerve, as the junction between fourth and fifth lumbar nerves lies immediately anterior to the process. He approaches the process by cutting a window from the ilium, and thus removes the opposing surface.

With erosion of the sacro-iliac joint, the surfaces may slip and the normal transverse process of the fifth lumbar vertebra on one side may be brought into contact with the ilium and be a cause of pain when the original lesion is consolidated.

The transverse process may also be brought into relation with the ilium by a scoliosis due to infantile paralysis, hip-joint disease or any other lesion producing a curvature.

There is no doubt that with all these irregular and asymmetrical joints, unusual strain is put upon the opposing surfaces, and adventitious bursæ form from time to time which become inflamed and give rise to pain. Such surfaces frequently show osteo-arthritic changes when other joints appear to be normal.

Ossification of the ilio-lumbar ligament may occur and this is usually associated with pain. In the 5 cases in my series, all complained of low back pain. In 1 case this was associated with pain in the gall-bladder area which led to some difficulty in the diagnosis. An X ray examination revealed calcification of the ilio-lumbar ligaments and a collection of gall-stones.

Doub refers to 40 cases observed at the Henry Ford Hospital. He states that the calcified ligaments and transverse processes were removed in 1 case with complete recovery

LUMBO-SACRAL ANGLE

Bardeen points out that in the embryo of 5 centimetres (9 weeks) the sacrum is nearly straight and in a line with the lumbar region. From this time onward the lumbo-sacral angle begins to form. When a child begins to walk, the lumbar curve is formed and the sacral concavity becomes more marked and the lumbo-sacral angle more salient.

In the adult, the lumbo-sacral angle is on the average 120 but this shows variations in both directions in the labouring class, chiefly in the reduction of the angle.

In the series which I have examined, the spinal columns with a high sacrum or with

Strasser Barnes Herrgott Braun Swartz, Spaeth, Roberts Fitch, Palmer and *Lambl* published a series of cases.

All the earlier workers looked upon the condition as being peculiar to the female sex, but *Codirolla*, 1908, *Brandenburg* 1910, and *McCordick*, 1912 reported a similar deformity in males. Many of the later writers are now trying to make out that the condition is a very common one and is much more common in males than in females. Thus, *Bowman* says it is a common cause of low back pain, while *Sir Arbuthnot Lane* goes so far as to say that spondylolisthesis is the normal condition in coal heavers. Further each writer appears to crowd into his list of cases a number in which the evidence of spondylolisthesis is very doubtful. Thus *Albee*, referring to one of his 8 cases says " It is questionable whether the case should be classified as a spondylolisthesis " Radiographically it is not, yet in his summary he says, " the author reports 8 cases."

Authorities differ in their interpretation of the lesion. This has not only had a bearing on their opinions as to the cause but on their interpretation of the radiographic appearances. In those cases which the author has regarded as the genuine, the upper

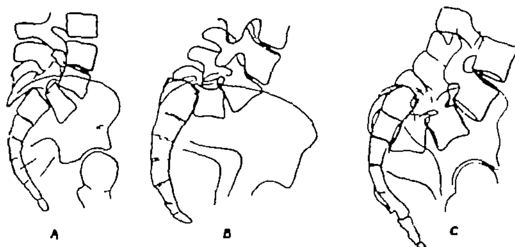


Fig 654. Tracings of the lateral radiographs of three spondylolisthetic patients showing 3 degrees of displacement :—

A. Girl aged 9 years. The fifth lumbar vertebra is losing the support of the sacrum and it is changing its plane in relation to the upper border of the sacrum.
B Girl aged 13 years The inferior surface of the fifth lumbar vertebra ppears to be moulded over the antero-superior edge of the sacrum.
C. Woman, aged 88 years. The inferior surface of the fifth lumbar vertebra is " gliding " down the anterior surface of the bodies of the sacrum. The dislocation was first recognised when she was 15 years of age.

vertebral column based on the fifth vertebral body and the anterior portion of its neural arch progressively slips over the superior surface of the sacrum. This is permitted either by the stretching of the interarticular section or of the pedicles or in some cases by dissolution at the interarticular section through a defect in development of the fifth lumbar vertebra and rupture of some attachments of the lumbo-sacral inter vertebral disc.

The lesion is a definite entity which presents certain characteristic clinical and radiographical appearances, but its pathology has not been fully determined. The term should be strictly reserved for those cases of dislocation of the lumbo-sacral joint which have been brought about by this gradual process and, therefore, should not be used to

ments are healed, little harm may result, but if there is a repetition of small degrees of trauma of this nature, the ligaments will be permanently altered the lumbo-sacral angle will diminish and arthritic changes will occur in the joints.

Herndon examined 408 cases of injuries to the back 08 per cent. of which he diagnosed as sprain—the most frequent site being in the lumbo-sacral region. The symptoms in these cases were pain, tenderness, stiffness and limitation of movement.

The antero-posterior radiograph of this condition may show a tilting upwards of the spinous processes and an apparent crowding together of the vertebræ. This may be interpreted as a crushing or slipping forward of the vertebral bodies. The lateral radiograph will show that the appearance is due to narrowing of the lumbo-sacral angle.

A Whitman has described 5 cases of this nature They complained of pain in the back in the region of the lumbo-sacral joint. Occasionally the pain radiated down the front and back of the thigh. The character of the pain varied from sharp agonising pain to chronic weakness and discomfort He calls the condition a pre-spondylolisthesis.

Hibbs[1] fusion operation was performed in 1 case to prevent an increase of the deformity

It is doubtful whether pre-spondylolisthesis is a fitting name for these cases. Though they show a breach of continuity of the elements of the fifth lumbar vertebra, the slipping may not occur

The author has had a patient under observation for several years whose radiographs showed a congenital defect of the neural arch of the fifth lumbar vertebra and a lumbo-sacral angle which was reduced to 90° following infantile paralysis. During the period in which the lumbo-sacral angle was rapidly reduced radiographs showed that the lower border of the fifth lumbar vertebral body projected beyond the anterior plane of the first sacral body Yet in spite of this exaggerated angle and the congenital defect of the neural arch, not the slightest slipping at the lumbo-sacral joint has occurred during the past 2 years.

Further breach of continuity as shown in a subsequent chapter is not an essential feature of spondylolisthesis.

This opinion is at variance with many authorities

Junghanns has described and illustrated a condition which he calls *Pseudo-spondylolisthesis*. *In this condition the radiographs show the anterior border of the fifth lumbar vertebra on a plane somewhat posterior to the general alignment of the anterior borders of the neighbouring vertebræ.* In other cases the displacement appears to be associated with chronic inflammatory changes in the articular surfaces. The cause of the deformity has not been determined. The first of the two cited cases of *Balensweig's* on p. 396 is interesting in this respect.

George and *Leonard* have illustrated a similar deformity

Another type of pseudo-spondylolisthesis is illustrated in Fig 357

SPONDYLOLISTHESIS

This is a term derived from the Greek meaning "gliding of a vertebra," and was first applied to the condition about to be described, by *Killian* in 1852. The condition had been observed and described previously by *Herbiniaux*, 1782 *Rokitanski* 1839 and *Belloc*, 1840 but it was not until *Neugebauer* in 1892 published his description of 101 cases, for the most part museum specimens, that much attention was paid to the condition.

Its chief importance, even at that time, was due to the difficulties which the deformity produced in obstetrics *Many other observers notably Lane, Bowman, Darling Lovett, Kleinberg, Balensweig Turner* and *Tchirkin, Napier Albee Widere Wiemens Magnuson*

body was 0 years. There are minor displacements at the joint which are often not discovered until the skeleton begins to show the signs of the stresses and strains of adult life, sometimes not until over 50 years These are essentially associated with atrophy and destruction of the lumbo-sacral disc. Periodic radiography of these cases do not show the progressive slipping of the early cases, indeed often the first radiograph shows definite indication of sclerosis of the approximated body surfaces and perhaps some ossification of the ligaments across the joint and the development of changes on the opposing surfaces simulating osteoarthritis It is probably in association with the latter that the symptoms develop which are the essential cause for the first radiographic examination. The projection of the anterior border of the fifth lumbar body over the upper border of the sacrum does not exceed half an inch The histories show some symptoms have been present for upwards of 10 years.

During the last few years it has been suggested that progressive slipping does not occur This statement occurs with what to the author appear exaggerated claims of the number of cases of spondylolisthesis observed Progressive slipping of all the early cases observed by the author was demonstrated by serial radiographs. No more conclusive radiographic proof of this slipping has been given than that by *H H Hitchcock*.

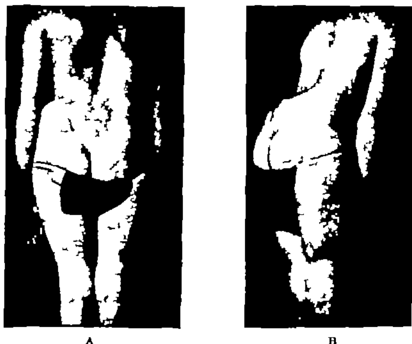


FIG. 356. Specimen of spondylolisthesis showing progressive elongation of the pedicles, funnel shape of spinal canal with herniation of disc into its base.

Fig 356 shows the two sides of a specimen of spondylolisthesis in the Royal College of Surgeons Museum. The cut surface shows a forward dislocation of the lumbar spine on the sacrum and a heaping up of the lumbo-sacral intervertebral disc behind the body of the fifth lumbar The neural canal widens gradually from the level of the second lumbar vertebra to the lumbo-sacral joint and with this widening the pedicles are drawn out into long processes, which in the photograph appear darker than the other bone—due to an artificial red staining of the processes for museum purposes The spine of the fifth lumbar is shown to project posteriorly further than the spinous processes of the vertebræ above or below and there is no suggestion of poor development of the neural arch The history states that there was no evidence of any injury This widening of the neural canal and the "drawing out" of the laminæ suggest that if the condition is due to trauma, the injury must have taken place in early life and a process of osteochondritis with plasticity of the bone permitted the elongation of the pedicles.

designate those dislocations of known cause and pathology such as acute fracture dislocations, tuberculosis, syphilis, pyogenic infections, tumours or cysts, which are better named under these terms, though they may have somewhat similar displacement and radiographic appearances.

The Lesion. The appearance of the typical spondylolisthetic patient is illustrated in Figs. 355 A and B. The prominent superficial spine is the spinous process of the fifth lumbar vertebra. As the deformity develops this spinous process and later the more proximal are tilted cephalically and become moulded where pressing upon adjacent



A B

Fig. 355, A. and B. Photographs of girl aged 16 years, showing the typical deformity of spondylolisthesis. Note the prominent spine of the fifth lumbar vertebra, and the outline of the sacrum which appears to be pushed backwards into a very superficial position.

spinous processes. The sacrum is "superficialised" and its outline is fairly clearly defined beneath the skin. The trunk is shortened and the normal lateral curvature of the trunk is broken by the prominence of the iliac crests due to the collapse of the lumbar spine into the pelvis. The other clinical appearances are referred to in another publication in which I have illustrated the nature of the lesion.* It is due to a progressive displacement through the lumbo-sacral disc the lower surface of the body of the fifth lumbar vertebra gliding forward over the superior surface of the sacrum until, being no longer supported, it slowly topples over and the inferior surface of the fifth lumbar comes into opposition with the anterior surface of the first sacral body down which it travels, pushing the sacrum backwards so that its outline beneath the skin may be recognisable. This is the lesion to which the term spondylolisthesis was given and which the author has only seen in twelve young girls between the ages of 9–15 years and in one boy aged 10 years. In one case the rate of progression from when it was first seen at the age of 9 years with forward displacement at the joint of 1 inch, until the anterior surface of the fifth lumbar had reached the anterior surface of the second sacral

isplacement. In the cases seen by the author radiographs have shown a forward displacement of about ½ inch beyond the anterior surface of the fifth body a breach of the neural arch has been visible in the inter articular region—the antero-posterior measurement from the posterior surface of the spine to the anterior surface of the body has been greater than in the adjacent vertebra and some reactive changes have been seen in the connecting tissues and on the opposing bony surfaces (see Figs 357 A and B) *Schmorl and Junghanns* have illustrated this lesion in male and female patients aged 68 and 82 years, but even in these there is no evidence of progressive slipping See also the note on *Balensweig s* case, p. 896.

It is more rare to see evidence of failure of fusion of the neural arch of the second or third lumbar vertebræ but whether the defect is in the neural arch of the fifth or in higher vertebra, if the fibrous union has been damaged the involved spinous process is tilted proximally and comes into close apposition with the spinous process above at which site reactive changes develop (see Fig 357)

FREQUENCY

Spondylolisthesis, a relatively rare condition, more common in females than in males, is diagnosed essentially on the radiographic appearances. The early authorities believed that the condition was confined to the female sex, but within recent years some writers have stated that men are equally or more commonly afflicted with the deformity Thus *A Whitman* states that spondylolisthesis is particularly prevalent in Wales, where it is sometimes referred to as miner's back. " Presumably this opinion is based on the oft repeated quotation from *Lane* namely spondylolisthesis is the normal condition in coal heavers." But an idea of its rarity can be gleaned from the fact that many radiologists of long and extensive experience have not seen a case. In *Köhler s* book we find this statement "I cannot recollect in about thirty years of Röntgen practice having seen an absolutely certain case." *R W Johnstone* in a recent paper states "It is the only case of the kind that I have ever seen, and is the only case of this deformity in the records of the hospital." In the *Robert Jones* paper of 1927 [*] the details and radiographic illustrations of 5 cases were given which had been discovered during the X ray examination of the lumbo-sacral spine of over 8 000 patients who complained of some discomfort or pain in this area. Since that time I have seen 0 other cases One was a boy aged 10 years. Twelve of these patients were females, all except one being under 20 years of age, the youngest 9 and the eldest 38 years The dislocation in one girl was first recognised when she was 15 years of age, but in spite of the wearing of various forms of back support the gliding has gradually progressed Except in the case of one man, who as a youth did heavy weight-lifting, none of these patients had done heavy work, and most of them were of relatively slim stature as in Fig 355 A. On the other hand, though many hundreds of men, engaged in mining and other heavy weight lifting occupations, have been radiographed for low back pain, no case of true spondylolisthesis was seen amongst them, though a number showed injury at the lumbo-sacral joint with a fixed displacement. It is the inclusion of such cases which permits the recording of large series of cases

ÆTIOLOGY

The variety of causes to which this condition is ascribed by different observers is sufficient evidence in itself to prove that either the cause is unknown or that it is brought about in many different ways It will be seen from the following brief summary that lesions of every structure entering into the formation of the lumbo-sacral joint have been blamed for the occurrence Many of the observers believe in the same fundamental

Forward displacement of the lumbar column through the disc space between the fourth and fifth lumbar vertebra is less frequent and usually not seen except in adults.

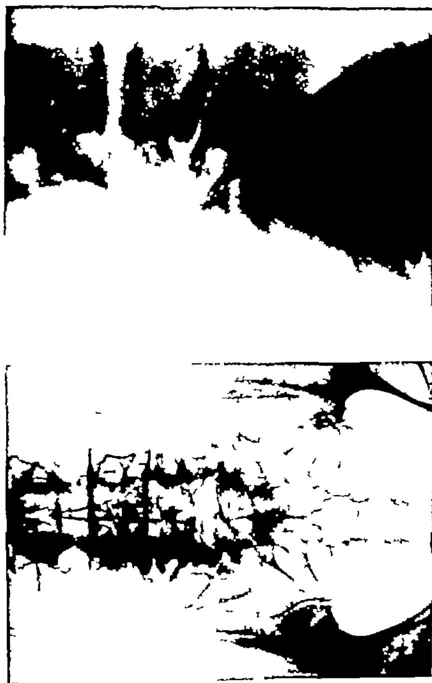


Fig. 257 A and B Spondylolysis of fourth neural arch with forward displacement of upper column on the fifth lumbar vertebra. Note defect in neural arch of fourth and secondary reactive changes in and round the involved disc

As previously indicated the fourth lumbar neural arch may develop its full characters though it may fail to fuse yet no displacement occur Possibly trauma is responsible for

Bowman and *Goin* say it is usually the result of trauma—the injury often being considered of minor importance They state "we believe spondylolisthesis is a much more common lesion than it is generally thought to be that many cases reduce themselves spontaneously and that many cases of so-called sacro-iliac slips are in reality cases of unrecognised spondylolisthesis."

Eden states "the change which occurs is not a dislocation but a displacement due to lengthening and bending of the interarticular portion of the last lumbar vertebra, as a result of which the vertebral column becomes displaced forwards and downwards The first sacral vertebra becomes gradually torn away by pressure and ankylosis eventually occurs in the morbid position."

\ *Mills* considers that the asymmetry of the articular processes of the lumbo-sacral joint renders the joint unstable, so that sudden rotation may cause fracture or dislocation in this area.

Hibbs confirms this opinion and states that a rotation deformity more marked on one side than the other is always found

Henry who states that he had had 5 cases in adult males in a year considers that it is due to the trauma of modern industry and for that reason is more common in men than women He is of the opinion that trauma presumably shears off the superior processes of the sacrum All his cases show nerve involvement. He says the lesion is a progressive one first a slight forward luxation of the fifth lumbar vertebral body gradual stretching of the ligaments, then dislocation progressing and increasing the instability He says that three of his cases showed congenital anomalies of the articular processes, which faced directly upwards

Rose and *Carless* state that "it arises from fracture of the articular processes of the lumbo-sacral synchondrosis or from imperfect development of the laminae or pedicles of the lowest lumbar vertebra as a result of which the pressure of loads carried on the shoulders or the weight of a pregnant uterus brings about the displacement."

Von Lackum says that the posterior part of the intervertebral disc being thinner diminishes its effectiveness as a shock absorber while the complete absence of spinous processes from the sacrum with thinner and longer ligaments increases instability

Ayers considers that spondylolisthesis probably results from the wearing away of the articular facets in a patient suffering from an exaggerated lumbo-sacral angle.

It will be obvious from a study of these conflicting opinions that different types of lesion are being discussed, and that the conclusions of some writers have been arrived at from the examination of but one or two cases, frequently without reliable radiographs in the requisite planes and the guidance of an experienced radiologist.

It has been stated by *Köhler* that the interpretation of the grosser and finer details of the fifth lumbar vertebra is one of the most difficult chapters in röntgenology " This is a fact which a number of writers on this subject have obviously failed to grasp

Amongst the chief causes to which the condition is ascribed are, congenital abnormalities, pregnancy so-called pre-spondylolisthesis " occupational strain, and trauma.

A familial tendency has been recorded by several authorities.

The excellent treatise "La Spondylolyse et ses consequences," by *P Clorieux* and *C Roederer* is recommended to the student.

Congenital Abnormalities. Defects of varying severity in the ossification and fusion of the neural arch of the fifth lumbar vertebra are relatively common. In some cases the defect consists merely of non fusion of the posterior arch in or near the spinous process, but it is in those cases in which the whole of the posterior segment, including the inferior articular processes, laminae, and spinous process, has failed to fuse with the anterior segment that the possibility of displacement has to be considered. The

cause but attach importance to a particular feature. Essential for the development of the lesion is a breach of continuity local destruction or softening of the bone which is responsible for maintaining the integrity of the lumbo-sacral joint—the defect of the fifth lumbar vertebra is often in the sector of bone between the superior and inferior facets but may be in the pedicles or the facets themselves Theoretically the defect may be due to faulty development, trauma, or any process which induces inflammatory reaction, with localised softening or destruction. The latter are associated with their characteristic clinical and radiological signs, but the typical spondylolisthesis of the young person, principally females, who have not been subjected to severe trauma, is without these inflammatory signs and we must look to weakness of structure which permits the deformity to develop with normal and not excessive function.

Any forward displacement produced by severe trauma or which develops as the result of localised inflammatory or neoplastic destruction should be regarded as fracture or pathological dislocations and should be treated accordingly *Neugebauer* formulated the theory that it is a static or traumatic deformity of the spine, favoured by the imperfect ossification of the laminæ of the fifth lumbar vertebra. He also advanced two other theories (*a*) that it is due to arthritis of the lumbo-sacral joint (*b*) that it is a pressure deformity of the normal vertebra resulting from prolonged physiological strain

Magnuson states that "it is a result of improper bony contact at the articulations and of a loss of bony continuity in the neural arch of the fifth lumbar vertebra." *Willis* and *Hey Groves* support this

Strasser considers that it is due to a primary arthritis of the lumbo-sacral articulations.

Chiari says that abnormal relations of the lumbo-sacral interarticular processes due to defective ossification bring it about.

Barnes favours a solution of continuity across the neural arch of the fifth lumbar vertebra between its superior and inferior processes on each side.

Herrgott thinks that inflammatory change following a breach of the vertebral arch by trauma is the cause.

Braun Swartz, and *Spaeth* all look upon congenital anomalies as the cause.

Rokitanski says atrophy of the articular cartilage leads to its development.

Lane and *Roberts* consider it due to excessive weight bearing which produces thinning and elongation of the neural arch.

Kleinberg and *Fitch* consider that the condition is due to trauma.

Kleinberg is of the opinion that there is an initial developmental defect in the lumbo-sacral region affecting the body and more particularly the ligamentous structure in these cases that the position of the lumbar articular processes in the sagittal plane favours a dislocation but he believes that trauma is the chief factor in the ætiology of this type of dislocation.

Darling says that it is due to trauma, favoured by congenital defect, that it has a gradual onset, and that the symptoms at the time of injury may be few

Palmer blames the tearing of the ligaments

Lambl says it is probably due to a congenital malformation remotely connected with fœtal hydrorrhachis, traces of which remain in the form of widening of the medullary ring.

Albee considers trauma to be the cause and states that the body of the vertebra is chiefly affected, whereas the laminæ and spinous processes may remain practically in place. The vertebra may be subluxated in part or its body and anterior half of its arch may be dislocated, while the spine and inferior articular surface and the posterior half of the arch may remain in place, and in time even be finally ankylosed to the sacrum.

sacral curvature; in fact it is relatively common following neglected rickets, in osteomalacia, and *osteogenesis imperfecta tarda*. In these cases the first, second and third bodies of the sacrum are often in a horizontal plane, and the lower segments are bent forwards at an acute angle, yet these patients do not develop spondylolisthesis

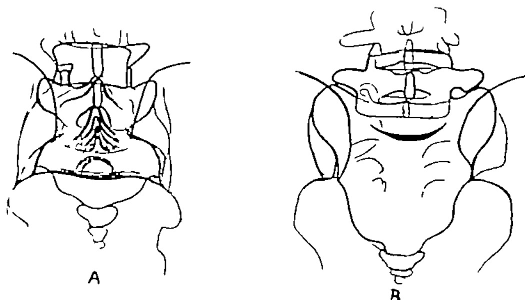


FIG. 358. Tracings of antero-posterior radiographs of two conditions which may be misinterpreted as spondylolisthesis.

A Acute lumbo-sacral angle—the plane of the anterior surface of the upper bodies of the sacrum being almost at a right angle to the plane of the anterior borders of the lumbar bodies. Note that the spinous processes of the sacrum and the fifth lumbar vertebra point in a cephalic direction and appear to be crowded together the spinous processes and laminae forming a series of inverted Y's. Because of the acute lumbo-sacral angle, the central X-ray was vertically over the plane of the superior surface of the sacrum and the radiograph shows the projection of the sacrum. The outline of the antero-inferior border of the fifth lumbar vertebra is obscured by the shadows of the sacrum.

With such a patient, if this central ray had been perpendicular to the plane of the brim of the pelvis, the radiograph would have shown the anterior border of the fifth lumbar vertebral body continuous with the transverse processes, but this projection would have been associated with a corresponding projection of the sacrum—an appearance which is not seen in spondylolisthesis, in which condition the fifth lumbar vertebral body would be seen to project forwards and to reduce the antero-posterior diameter of the pelvic brim.

B. A normal lumbo-sacral angle associated with ossification of the attachments of the anterior common ligament to the superior border of the sacrum. The crescentic line across the shadow of the first sacral body indicates lipping of the antero-superior surface of this vertebra and not the inferior border of the fifth lumbar vertebra, the outline of which is indicated at a higher level. In some cases this crescentic line is as fine as if it had been drawn with a pencil; in other cases it is thick and dense and even irregular

Instead of this line indicating spondylolisthesis its presence proves that forward displacement of the fifth lumbar vertebral body has not occurred, otherwise it would have been obscured by the shadow of the latter

In the latter condition the sacrum, instead of being horizontal, is vertical, and takes up the position which I have previously described as a "superficialised" sacrum.

The wedging together of the spinous processes of the lumbar vertebræ, providing that the union between the superior and inferior articular processes remains intact, is more likely to check than initiate, spondylolisthesis, otherwise in those cases in which there is a very pronounced lumbo-sacral curvature (see Fig 358, A) slipping would occur

apposition of the inferior articular processes of the fifth lumbar vertebra with the articular processes of the sacrum will check any forward or backward displacement at the lumbo-sacral joint, if these are facing in an anterior or posterior plane, as long as the vertebræ concerned with their associated lumbo-sacral intervertebral disc are intact and unaffected by disease or injury but if any solution of continuity or softening has occurred in the disc or between the superior and inferior articular processes of the fifth lumbar vertebra, displacement may occur at the joint owing to the super-incumbent weight, acting as a shearing strain, overcoming the resistance of the weakened structures. These features are seen in some cases of spondylolisthesis. The spondylolysis can be recognised in some films by the cephalic direction of the separate neural arch, which on antero-posterior projection appears to have a greater density than its fellows, and is associated with what appears as an oblique fissure at the site of the pseudarthrosis a site which may be emphasised by added bossing of new bone—probably the result of the small repeated traumata of function at the weak focus. But many subjects have been dissected in which the posterior segment of the arch (the inferior articular processes, laminæ, and spinous process) has no bony union with the anterior portion of the vertebra. In spite of the non-bony union the vertebral processes have developed normal characters, and as I have illustrated in a previous paper [11] it may not be possible to detect this failure of fusion of the posterior segment by radiography even after the dissected specimen has been removed from the body It is therefore reasonable to suppose that these defective vertebræ may be present and yet remain undetected by radiography because there is no displacement. On the other hand many spines show very obvious defects at this site yet no displacement. Nevertheless, in a number of cases of spondylolisthesis, radiographs indicate that this posterior segment is ill-developed or un united. In some cases this may be due to the acquired deformity and changes consequent upon it, but in others the defect appears to have been present before the displacement. I have published [11] a photograph of a specimen in the Museum of the Anatomical Department of the University of Birmingham. The posterior segment of the fifth lumbar vertebra is missing, and as there is no evidence of fracture, and as well-developed and worn articular processes are present on the sacrum belonging to it, obviously this is a specimen in which the posterior segment has failed to fuse

There is no evidence in this specimen that spondylolisthesis occurred.

I have also published [18] the photographs and radiographs (see Fig 367) of a baby girl, aged 3 years, which show a dislocation at the lumbo-sacral joint in association with spina bifida occulta, but I do not regard this as being a true case of spondylolisthesis because there is no evidence of gradual slipping

Pregnancy The vital significance of spondylolisthesis in a pregnant woman has been appreciated by obstetricians for many years but it is very improbable that the lesion has been initiated by pregnancy In some women the minor displacements may give rise to difficulty in childbirth. One woman of 28 years of age had to be induced at 8 months because the pelvic brim measurements had been reduced by the displacement. The pregnancy did not advance the displacement.

R W Johnstone and *A Thompson* have published the details and radiographs of a true spondylolisthetic patient who gave birth to a full time infant without any marked difficulty

Pre-spondylolisthesis. This unfortunate term was coined by *Armitage Whitman* and applied to those cases in which the lumbo-sacral angle approached that of a right angle, because, he states, "It seems reasonable to assume that these patients represent the *first and secondary stages* along the road leading to complete lumbo-sacral dislocation" Now it is not uncommon to find adult men and women with a most exaggerated lumbo-

It will be seen in the radiographs of all genuine cases which have been published. The degree of slipping in each case varies, but this does not appear materially to affect the general contour of this line. The line was recognised when the lateral radiograph showed a projection of the lumbar spine of only half an inch over the sacrum, and the line was prominent in a case where almost the limit of slipping had been reached, *i.e.*, with the inferior surface of the fifth lumbar vertebra in close apposition to the anterior surface of the third sacral body In the young child, probably owing to the lack of density of the vertebral body the bow line is not so well defined as in the adolescent and adult. I have never seen any lesion other than

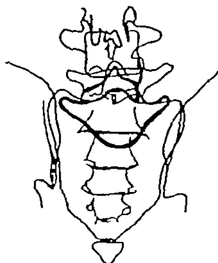


Fig. 361A. Tracing from an antero-posterior radiograph showing characteristic "bow-line" of the fifth lumbar vertebra projected over the shadow of the vertical sacrum in spondylolisthesis. There is a suggestion that the neural arch is un-united to the body



Fig. 361B. Tracing of radiograph showing ossification of the anterior common ligament of the lumbo-sacral joint producing a dense D-shaped band which may be mistaken for the characteristic line of spondylolisthesis.

a dislocation of the fifth lumbar vertebra on the sacrum produce such an appearance The lesion producing a line liable to be mistaken for it is ossification of the anterior common ligament around the rim of the superior border of the first sacral body but it will be seen from Figs. 358, B and 361 B that these shadows are distinctive and should not be confused one with the other Incidentally it is probably the discovery of irregular ossification in this area which leads certain observers to report spondylolisthesis as a common deformity

Associated with this projection of the body and transverse processes, the neural arch with the spinous process appears to be pointing in a proximal direction (see Fig 362) With the development of the deformity adjacent superior lumbar spinous processes are forced into contact, directed cephalically and moulded. This latter appearance which is normal in patients with an exaggerated lumbo-sacral angle, has led to the error of reporting such cases as spondylolisthesis.

In spondylolisthesis the sacrum appears clinically to be pushed backward—it appears to be more superficial than normal, and this is indicated on the antero-posterior radio-

As will be seen from Fig. 359 the outline of the anterior surface of the fifth lumbar vertebra when viewed from above is that of a bow: the anterior convex outline of the body merging imperceptibly on each side by a gradual concavity into the outline of the lumbar vertebral transverse processes. *This bow outline when projected into the shadow*



FIG. 359. Radiograph of the fifth lumbar vertebra from the superior surface, showing the characteristic bow-line of the anterior surface of the body and transverse processes.

of the vertically placed sacrum (see Figs. 361 A and 362) *is characteristic of the radiographic appearance of spondylolisthesis.* It was seen in all progressive cases and was the line which previously alone led to the correct diagnosis. Though the significance of this characteristic line, with the greater facility for obtaining lateral radiographs, may not be appreciated, it has lost little of its value since I first described it in 1927, for it permits



FIG. 360. The characteristic bow-line of spondylolisthesis.

of the diagnosis in the many cases in which antero-posterior radiographs only have been taken, *i.e.*, in those cases where the clinician has suspected a lesion of the hip or sacro-iliac joints or pelvis. Obviously the bow outline may be shown when the lumbo-sacral angle is so exaggerated that the superior surface of the fifth lumbar is facing forward, *but in that case there is this difference, the sacrum will show a similar projection,* and the outline of the superior surfaces of its bodies may also be seen.

the antero-superior and inferior spines becoming superimposed on the shadow on the fifth lumbar vertebral body all outlines of the latter except its proximal surface being obliterated by the relative density of the ilium as in Fig 363.

Bowman considers that the dislocation should be judged from the alignment of the posterior surfaces of the vertebral bodies, but *Le Wald* has pointed out that in doing so



Fig 363. Pseudo-spondylolisthesis. Tracing of lateral radiograph showing obliteration of the outline of the anterior surface of the fifth lumbar by denser shadow of the antero-lateral borders of the ilia. The posterior surfaces are in normal alignment and the anterior surface may be judged by a line joining the antero-superior borders of the fifth lumbar and first sacral vertebræ. The antero posterior radiograph showed a normal lumbo sacral junction.

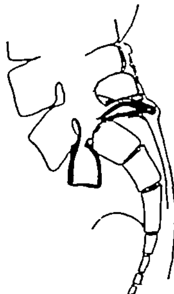


Fig. 364 Tracing of lateral view of spondylolisthesis showing elongation of the lateral processes of the neural arch and compression of the spinous process between the upper border of the sacrum and the fourth lumbar spinous process. The radiographs show definite increase in the density of the compressed neural arch (see Fig 363).

the diagnosis has been wrongly made by mistaking the shadow of the proximal surface of the lateral mass for the body of the first sacral vertebra.

The shadow of the antero-lateral border of the ilium may be so projected that it is in alignment with the anterior border of the displaced lumbar body and the dislocation thereby masked.

The recognition of the slight degrees of displacement such as we see in adults may not be easy particularly when the disc space is little diminished. Slight forward displacement of one or more lumbar bodies may be associated with arthritic changes in the facets. With the quality of modern lateral radiographs the detail of the opposing as well as the anterior and posterior borders of the fifth lumbar and first sacral bodies

graph by the almost vertical borders of the sacro-iliac joints at which the respective bones show little overlapping much less than the normal (see Fig 362)

This projection of the sacrum will be an additional help to the student in his recognition of spondylolisthesis if he is not satisfied with the projection of the fifth lumbar vertebra alone, and it will help him to exclude from the diagnosis such conditions as ossification of the lumbo-sacral anterior common ligament and diminution of the



FIG. 362. Antero-posterior radiograph of spondylolisthesis showing the characteristic line of the anterior surface of the fifth lumbar vertebra and the flattened sacrum with its almost vertical sacro-iliac joints in which little overlapping of the sacrum and ilium is to be seen.

lumbo-sacral angle Though the characteristic line of the fifth lumbar vertebra has been present in those cases of dislocation of the lumbo-sacral joint due to severe trauma or localised bone disease (tuberculosis, secondary neoplasm, and hydatid cyst), it has not been associated with the same projection of the sacrum and the bone has shown the concomitant evidence of these lesions. As stated in the opening paragraph of this paper such dislocations, strictly speaking, should not be included under the heading of spondylolisthesis.

LATERAL RADIOGRAPHS

To-day a good quality lateral radiograph will show unmistakable evidence of the dislocation, but unfortunately the projection of the shadows of the pelvic bones become superimposed on those of the bodies of the fifth lumbar and first sacral vertebræ and lead to misinterpretation. In some cases the condition has been reported present when it did not exist in others its presence has been missed The former error has been found to be due in some cases to the shadow of the antero-lateral border of the ilium, between

Forward dislocation of the sacrum as in Fig 366, though not uncommon in tuber culosis, has not been observed by the writer in true spondylolisthesis



FIG 366. Tracing of lateral radiograph showing anterior displacement of the fifth lumbar and sacral vertebræ due to lumbo-sacral tuberculous caries.





FIG. 367 Tracing of radiograph showing dislocation of the lumbar vertebræ on the sacrum in a child 3 years of age. It is associated with *spina bifida occulta*

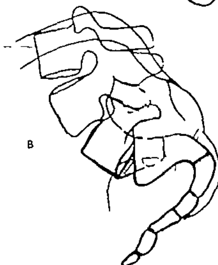


FIG. 368.

A. Tracing from radiograph showing osteomalacia of the pelvis. The first sacral vertebra shows the outline of its superior surface, and the pelvic brim is markedly deformed and contracted.

B Osteomalacia—lateral radiograph of same pelvis as A, showing marked increase in the lumbo-sacral curvature with acute flexion of the sacrum in the region of the second and third bodies.

In the extreme cases the inferior surface of the fifth lumbar body is shown in close apposition to the anterior surface of the first sacral body with which it may be ankylosed or it may "glide" still lower as in one case of the author's, when it reached the third

can be seen. Though the outlines of the anterior aspect of the bodies may show no apparent breach in the lumbo-sacral curve, a very definite forward displacement of the fifth lumbar may be detected from the posterior surfaces of the bodies Supporting



Fig. 383 Lateral radiograph of spondylolisthesis showing the anterior projection of the lumbar spinal column on the sacrum, and the lengthening and condensation of the spinous process of the fifth lumbar vertebra.

evidence will be often obtained by examining the degree of projection of the fifth lumbar spine—if this is normally developed, and it often is, it will be seen to project backwards further than the fourth lumbar and the antero-posterior measurements from the tip of the spine to the anterior surface will be greater than that of the fourth. Further some breach of continuity of the neural arch may be detected or it (including the spinous process) may show reactive sclerosis. (See Figs. 384 and 385) But, as indicated backward displacement of the spinous process with breach of continuity of neural arch may occur without displacement of the bodies yet it does increase the overall antero-posterior measurement.

When the disc space is diminished and the bodies are closely approximated the forward displacement of the fifth lumbar will be obvious. In these cases evidence of ossification of the connecting ligaments on the borders of the involved vertebræ, together with reactive sclerosis of the opposing bony surfaces and at the site of a breach in the neural arch, may be seen in adults

The progressive lesion will be readily recognised because of the degree of displacement, and radiographs will clearly show the fifth lumbar projection over the sacrum; further the antero-posterior radiograph will give the characteristic bow line on the flattened sacrum.

Forward dislocation of the sacrum as in Fig 366 though not uncommon in tuberculosis, has not been observed by the writer in true spondylolisthesis.



Fig. 366. Tracing of lateral radiograph showing anterior displacement of the fifth lumbar and sacral vertebræ due to lumbo-sacral tuberculous caries.





Fig. 367 Tracing of radiograph showing dislocation of the lumbar vertebræ on the sacrum in a child 3 years of age It is associated with spina bifida occulta.

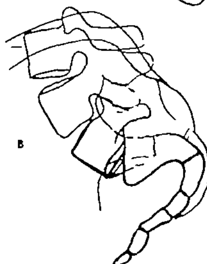


Fig. 368.

A. Tracing from radiograph showing osteomalacia of the pelvis. The first sacral vertebra shows the outline of its superior surface and the pelvic brim is markedly deformed and contracted.

B. Osteomalacia—lateral radiograph of same pelvis as A, showing marked increase in the lumbo-sacral curvature with acute flexion of the sacrum in the region of the second and third bodies.

In the extreme cases the inferior surface of the fifth lumbar body is shown in close apposition to the anterior surface of the first sacral body with which it may be ankylosed, or it may "glide" still lower as in one case of the author's, when it reached the third

can be seen. Though the outlines of the anterior aspect of the bodies may show no apparent breach in the lumbo-sacral curve, a very definite forward displacement of the fifth lumbar may be detected from the posterior surfaces of the bodies. Supporting



FIG. 363. Lateral radiograph of spondylolisthesis showing the anterior projection of the lumbar spinal column on the sacrum and the lengthening and condensation of the spinous process of the fifth lumbar vertebra.

evidence will be often obtained by examining the degree of projection of the fifth lumbar spine—if this is normally developed, and it often is, it will be seen to project backwards further than the fourth lumbar and the antero-posterior measurements from the tip of the spine to the anterior surface will be greater than that of the fourth. Further, some breach of continuity of the neural arch may be detected or it (including the spinous process) may show reactive sclerosis. (See Figs. 361 and 365.) But, as indicated, backward displacement of the spinous process with breach of continuity of neural arch may occur without displacement of the bodies, yet it does increase the overall antero-posterior measurement.

When the disc space is diminished and the bodies are closely approximated the forward displacement of the fifth lumbar will be obvious. In these cases evidence of ossification of the connecting ligaments on the borders of the involved vertebræ, together with reactive sclerosis of the opposing bony surfaces and at the site of a breach in the neural arch, may be seen in adults.

The progressive lesion will be readily recognised because of the degree of displacement, and radiographs will clearly show the fifth lumbar projection over the sacrum; further, the antero-posterior radiograph will give the characteristic bow line on the flattened sacrum.

The papers by *Pokorny Dietrich Kershner* and *Stewart Krause* and *Langsam Polatin Fieldman Harris* and *Horwitz, Krause* and *Scherb* and *Stalker* contain good illustrations and descriptions of examples of these conditions.

In the young individual trauma may produce a narrowing of the lumbo-sacral angle and lead to the development of spondylolisthesis. In the adult severe trauma to



Fig 369 A and B Disc Repercussion fractures of dorsal bodies due to convulsive therapy Note that the compression (indicated by the dark bands) affects in this case only the superior surfaces.

the lumbo-sacral area may result in fracture dislocation of the lumbo-sacral joint, an injury which produces radiographic appearances resembling those of spondylolisthesis. The trauma damages the ligaments and the intervertebral discs The former may become ossified The intervertebral space becomes lessened owing to atrophy of the disc and later some osseous metaplasia may occur within it. After several years, evidence of the injury will be given by the radiograph in the shape of buttresses of new bone around the injured joint and it will be found that little or no increase in the forward displacement of the lumbar vertebræ on the sacrum has occurred In other words spondylolisthesis has not developed. The commonest fracture of the spine is the compression fracture of the vertebral body (see Fig 371) This type of fracture is chiefly seen in the fifth

sacral body With partial dislocation the inferior surface of the fifth lumbar vertebral body may become moulded over the antero-proximal surface of the first sacral body and evidence of ankylosis may be shown in this position

There is nothing in the radiographic appearance of any of my cases to support the opinion expressed by *Lovett* that " the essential point is not so much a subluxation of the body as the antero-posterior elongation of the body This always exists, and is apparently the pathological condition peculiar to this situation and this condition."

The teaching of these findings is that a diagnosis should be made on good radiographs only taken in both the antero-posterior and lateral planes. Particularly is it necessary to correlate the appearances shown on the radiographs taken in the two planes in cases where only a slight degree of displacement has occurred, as in cases of traumatic dislocation.

For judging minor displacement various lines have been described. The points of contact with these depend on clear definition of the vertebral margins for their accuracy Unfortunately this essential feature is often missing

DEFORMITIES DUE TO INJURY

Deformities of the lumbo-sacral region of the spine due to fracture are more common than formerly believed. When such a fracture occurs it is due to very severe trauma.

Fractures of the dorsal bodies in childhood are usually in the neighbourhood of the fifth and sixth They take the form of compression and the line of the fracture may not be visible. As the result of falls, fractures have been seen in all the column from th fourth to the ninth (at a rather higher level than the lesion in kyphosis dorsalis juvenilis which is centred round the eighth and ninth dorsal vertebræ) Similar fractures showing this distribution are seen following tetanus in childhood, but it should be remembered that in most cases of *osteogenesis imperfecta* the vertebral bodies sometimes only the upper dorsal, show general compression (see also " Vertebra Plana ").

With the introduction of convulsion therapy for schizophrenia we are seeing multiple compression fractures in the neighbourhood in adults. *Of 11? patients so treated by Dr O'Reilly* the author reported that " of the 60 females with ages ranging from 18–60 years no less than 12 showed disc repercussion compression of the superior border of the vertebral bodies The affected vertebræ ranged from the third to the eighth the fifth being the most common All except one doubtful case showed multiple affected vertebræ the fourth, fifth and sixth being the most common grouping Of the 57 males, with ages ranging from 16–50 no less than 23 showed the characteristic compression of the superior surface of several dorsal bodies the fifth, sixth and seventh being the most common grouping

In one case all the lower 9 dorsal bodies showed these fractures of their superior surfaces

The author has used the term Disc Repercussion Fractures for these injuries because they give the impression that the disc surfaces have been hammered out by repeated blows It seems evident that a great amount of force is rapidly and repeatedly exerted in the vertebral column, and especially that portion which is least mobile The radiographs show an increased density with compression of the affected vertebral body and concavity of the disc surfaces which may not be so apparent in the antero-posterior as on the lateral radiographs No fracture line can be seen in this type of lesion though in a few cases definite compression fractures of the bodies could be made out. After an interval the density of the compressed surface disappears and the affected body may then present the late appearances of the ordinary fracture The radiographic features of these lesions in the post-mortem subject is shown in Fig 370

This rather suggests that a greater degree of deformity will result if the injured vertebral body *is not relieved of all compression* during the process of repair. It has been shown recently by *Davis*, *Böhler* and *Watson Jones* that even when a vertebral body has been compressed by injury it is possible by hyperextension to pull the fragments of the body into an almost normal position.

Such fractures may be produced in old people with relatively trifling injury and therefore may be quite unsuspected until perhaps a definite kyphosis is seen. If this has taken several weeks to develop, its appearance may not be related to the injury and may give rise to a suspicion of pathological destruction of the bone, *e.g.*, tuberculosis



Fig. 372. Radiograph showing lipping of the left borders of the second and third lumbar vertebræ. The patient gave a history of injury to this part of the back 2 years before. *Kümmel* has shown similar appearance of the same vertebræ in a girl of 17 years as the result of typhoid fever.



Fig. 373. Radiograph showing the bone and joint changes five years after an accident which damaged the lumbo-sacral joint. It shows a sclerosis of the bone in the neighbourhood of the left side of the lumbo-sacral joint, and ossification of the connecting ligaments, also sclerosis and lipping of the bodies of the second and third lumbar vertebræ on the right side, the concave side of the curvature.

or neoplasm. It is probably owing to this delay in the production of the deformity that this appearance of the vertebral body has been described as *Kümmel's disease*, which is defined as a non-tuberculous rarefying osteitis of the vertebral bodies accompanied by softening and collapse. A series of radiographs of a man aged 23 years taken immediately, 9 months and 17 months after fractures of the tenth and eleventh dorsal vertebræ showed gradual consolidation with the appearance of a Schmorl's node. In the young person, though radiographs immediately after damage to the spine may show no abnormality, serial radiographs may show the progressive development of vertebra plana (see Fig. 381, A and B).

and sixth cervical region and the twelfth dorsal and first lumbar vertebræ. The fracture is usually due to forced hyperflexion, but the force necessary to produce the fracture appears to vary greatly in different individuals. It is seldom that this type of fracture is seen in the lower lumbar region. The clinical and radiographic evidence will vary with the degree of trauma and the condition of the bone.

As a general rule, it may be said that the more obvious the clinical deformity the greater the bone or joint abnormality shown on the radiograph.

The observer should be wary of the fourth dorsal vertebra. The neck of the scapula



FIG. 370. Post mortem specimen showing nature of compression produced by convulsion in osteoporotic spine.



FIG. 371. Lateral radiograph showing wedge-shaped compression fracture of the body of the twelfth dorsal vertebra due to sudden hyperflexion of the trunk.

with the glenoid may be projected into its shadow and produce the appearances which have been mistaken for a compressed fracture.

In a previous publication it was pointed out that in some cases, if the patient is examined in the first few days, little sign of the deformity may be seen. The patient will usually complain of pain and tenderness in the region of the fracture, and there may be obliteration or departure from the normal antero-posterior curvature. Antero-posterior and lateral radiographs may not show any definite bone deformity. Gradually with the absorption, organisation and compression of the damaged tissues, the deformity begins to show. Several patients were radiographed within a few hours of their injuries and the radiographs showed little sign of compression of the vertebræ, but a week or so later a definite wedge-shaped compression of the vertebral body could be detected on the lateral radiograph; no attempt had been made in the interval to prevent movement.

Reference has been made by the author to a series of radiographs of a child, in whom, a few days after birth, the parents noticed a small lump in the dorso-lumbar area. At the age of 2 months the child was seen by the writer and found to have a knuckle deformity in the dorso-lumbar region of the spine. There were no local signs of inflammation, and the child did not show any evidence of local tenderness. With the exception of the posterior surfaces the eleventh and twelfth dorsal vertebræ appear to have been destroyed, and there is a suggestion of erosion of the upper border of the first lumbar vertebra. A minute detached particle of bone is shown above, and on a plane with the anterior border of the first lumbar vertebra. Radiographs taken at intervals during the next 3 years show that, under treatment, the remnants of the affected vertebræ have developed, but they present a woolly anterior border as in cases of osteochondritis. The child has no pain, is quite happy and shows good development and for the past 12 months has worn no back support. There has been no evidence of an inflammatory lesion, and the writer considers that the lesion might have been due to trauma during or soon after child birth.

If such cases are watched with serial radiographs it will be seen that the gap between the unaffected vertebræ will gradually diminish until they are in close association. To do this the lower column usually advances in front of the upper column and its curvature is increased to such an extent that the anterior surface of the top vertebral body is facing the anterior inferior surface of the lowest body in the upper column. Some moulding of these surfaces and the included remnants of the damaged vertebræ takes place, the detached fragments may also show signs of growth—until after the age of 5 it will be impossible to distinguish the lesion from a congenital maldevelopment for no sign of inflammatory reaction can be detected at any time. It is possible that some of the irregularities of the lumbo-sacral region may be induced in this way.

In another case, a girl of 11 who had been injured some months before, the radiographs show fusion of two of the vertebral bodies and deformity of the upper border of the lower adjacent body with no evidence of osteoporosis or abscess formation. The features in this case also suggest that the condition is one of osteochondritis following trauma. That as a direct result of trauma the lesion described as vertebra plana can develop is illustrated by Figs. 381 A and B. *Calvé* has recorded and illustrated complete collapse of isolated vertebral bodies in patients who have shown no clinical signs or symptoms of bone tuberculosis. On the other hand, similar appearances may follow tuberculous disease, as recorded by *Calvé* and by the writer who has also seen this lesion develop from a xanthomatous focus. In these all trace of the abscess completely disappeared.

Treatment. Cases of osteochondritis with pain as the outstanding feature should be kept recumbent on a frame for 3 to 6 months. Further recumbent treatment should be decided by the radiographic appearance of plasticity of the bone. Milder cases may be treated by the wearing of a block leather back support until the radiograph shows the bones have consolidated.

In those cases in which there is any radiographic evidence of damage to the vertebral bodies the patient should be fixed on a frame in slight hyper-extension after the manner illustrated by *Watson Jones*.

COLLAPSE OF THE VERTEBRAL BODIES

Collapse of the vertebral bodies may occur as the result of forcible hyperflexion of the spine due to heavy weights falling or being carried on the shoulders, or due to the lifting of heavy weights. Such deformities are seen in colliers as the result of the falling

date did not reveal any evidence of fracture or displacement but his clinical condition indicated a severe injury had been sustained He had temporary paresis. A radiograph 23/2/37 showed some narrowing of the disc space between the twelfth dorsal and first lumbar vertebral bodies with forward displacement of the lower vertebral column at this site. Radiographs 4 months after showed that the displacement was much less, the disc space was further reduced, and there was evidence of ossification of the connecting ligaments and tissues between the affected bodies Two years after fusion of the bodies was shown Forward displacement of the lower column has been seen to follow localised disease.

KÜMMELL'S DISEASE

This condition was first described by *Kümmell* in 1895 It has been defined as a non tuberculous rarefying condition of the vertebral body which results in its compression and deformity

The lesion is usually related to trauma, and can be diagnosed only by radiography

The author has seen several series of radiographs, taken at intervals, of patients with injured spines, and from a study of these he concludes that, while a radiograph immediately after trauma may as in the case of the injured scaphoid, show the appearances of normal vertebræ, a radiograph after an interval of 2 or 3 months may show relative osteoporosis of one or more vertebral bodies, and some compression of these bodies (see Fig 381). Subsequently radiographs will show consolidation of the deformed structures. This is possibly due to injury sustained by the cancellous bone, and as in the case of the carpal scaphoid, changes may not be apparent until the process of repair has removed damaged but supporting trabeculæ It was because of this that one suggested in a previous publication the necessity for hyper-extension in cases where the signs and symptoms suggested injury to the vertebral column, though the radiographic appearances were negative.

Radiographs of the cervical spine of a patient injured in a motor accident showed no bone changes for several weeks, but ultimately changes as in *Kümmell's disease* were shown. No deformity resulted as the neck had been kept supported in a plaster case owing to the pain caused by the injury

In the case described by *Rigler* the patient, a woman of 55, fell down some steps. He states lateral radiographs taken 2 months after showed no abnormality of the vertebræ, but radiographs taken 9 months later showed crushing of the bodies of the eighth and tenth dorsal vertebræ The radiographs illustrating the article show general osteoporosis of the vertebræ

Blaine [1] *Cardis Walker* and *Oliver* and *Reisner* [1] have also published radiographs showing the typical changes.

In some cases the process of repair is slow and the patient does not seek medical attention until a kyphotic deformity often associated with pain, has developed

The clinical signs and symptoms may suggest tuberculosis of the spine, but this disease can usually be excluded by radiographic examination of the area. Tuberculosis of the dorsal spine can be recognised by the fusiform paravertebral abscess shadow surrounding the deformed vertebral bodies, (a similar shadow due to a hæmatoma may be produced by trauma, but it is soon absorbed) and in other sites, by the shadows of calcium within the older abscesses. Further tuberculosis does not spare the intervertebral discs, and the involved vertebral bodies show a very irregular erosion. In healed tuberculosis, the deformed vertebral bodies may present appearances not unlike those produced in *Kümmell's* disease.

In some cases it may be very difficult to decide on the nature of the bony deposits.

CHAPTER XVI

THE SPINE (*continued*)

DORSO-LUMBAR AREA

The commonest congenital abnormality in this area is the so-called "lumbar rib" to which reference has been made elsewhere [a]. These rudimentary ribs are not of serious clinical importance if their radiographic appearances are appreciated. The smaller examples resemble in size and shape transverse processes which, in some cases, show a joint resembling the line of a fracture. Symptoms of nerve pressure have been attributed to them.

The most important congenital abnormalities of this area are anterior and posterior spina bifida and hemivertebræ. The latter if asymmetrical, are frequently associated with scoliosis and other hemivertebræ at the lumbo-sacral or cervico-dorsal junction, as in Figs. 347 F and H.

Schertlein, reporting on the anomalies of this area, states that they are present in 10 per cent. of males and 3 per cent. of females.

Hansen [a] has illustrated an anterior spina bifida of the eleventh dorsal vertebra in a girl, aged 14 years, who developed pain in the back and paralysis of the legs. The antero-posterior radiographs shows a similar appearance to Fig. 347 G, but the lateral radiograph suggests a wedge-shaped compression of the faulty vertebra with kyphotic deformity. The dorso-lumbar area of the spine is a common site for compression fractures of the vertebral bodies and for tuberculous caries. These lesions are described in their appropriate chapters.

Congenital abnormalities of the dorsal spine are commonly associated with rib anomalies. The latter, in their simplest form, appear as a bifurcation of the anterior extremity or fusion of two adjacent ribs just beyond the necks. Fusion of five or six ribs may occur in a similar situation, and a large gap may be left in the bony thorax due to this, as in Fig. 347 D.

Torbin and *Jalin* record the details of a man, aged 82 years, with spina bifida occulta of the third and fourth dorsal vertebræ; some importance is placed by them on a severe injury which his mother sustained during pregnancy.

Marked scoliosis was seen in a number of cases due to single hemivertebræ in the mid-dorsal area.

A marked defect in the ossification of the posterior surface of a vertebral body may be due to persistence of notochordal tissue and not to disease. *Junghanns* has illustrated several excellent examples of this defect with photographs of the post mortem specimens.

CERVICO-DORSAL AREA

The most important congenital anomaly in this site is the "cervical rib" because it may be associated with pressure upon the nerve trunks of the brachial plexus, or the large vessels (see Fig. 373).

Radiographs of patients with symptoms of pressure on the brachial plexus may show unilateral or bilateral anomalies, such as long transverse processes to the seventh cervical vertebra or ribs from this vertebra of varying size. If bilateral, they are rarely symmetrical, so that symptoms may be produced on one side only. The pressure in some cases is due to a fibrous band uniting the accessory rib with the normal first rib

in of material from the roof of a mine also in patients after tetanus and convulsive therapy (see p 392)

The possibility that osteoporosis and collapse of one or more vertebral bodies is due to diffuse myelomatosis with a grave prognosis should indicate the necessity for sternal puncture.

In **senile osteoporosis** collapse of one or more vertebral bodies may occur without any definite trauma the nature of the lesion in this case will be inferred from the biconcave shape of the unaffected bodies, the biconvex expansion of the discs and the general *osteoporosis of the vertebræ.* Similar appearances have been seen in cases of osteoporosis associated with basophil adenomata of the pituitary and tumours of the suprarenal. *Graham Lescher* and *Robb-Smith* have published an account of a patient with a carcinoma of the adrenal cortex whose spine presented these radiographic appearances.

In some cases of senile osteoporosis in debilitated women there may be a considerable degree of decalcification but little evidence of the compression deformities which characterise the lesions of long duration not incurring recumbency such as osteomalacia and Paget s disease.

Collapse of one or more vertebral bodies may also occur in tuberculosis, typhoid fever and other infectious diseases, lymphadenomata or metastatic carcinoma, but these present other radiographic features Radiographs of post mortem specimens showing these destructive lesions are published by *Schmorl* and *Junghanns* See also "Osteomyelitis," p 440

Calvé [1] has described and illustrated collapse of a vertebral body in a boy of 2½ years. Though this was accompanied by signs suggestive of tuberculosis, he regards it as a non tuberculous lesion (see pp. 413–6)

DISLOCATION OF LUMBAR VERTEBRÆ

Wollenberg illustrates a congenital forward dislocation of the vertebral column on the second lumbar vertebra, which has a smaller body than the other vertebræ He states that the mother and sister of the patient showed a similar defect.

Dislocation at this level was seen in 3 cases of chondro-osteo-dystrophy 2 of these being sisters

In 2 other cases of the same dystrophy in my series, the second lumbar vertebral body had only a little more than half the antero-posterior dimension of the adjacent vertebræ which therefore projected forwards beyond the anterior aspect of the second. It is possible that *Wollenberg's* case is of a similar nature.

The condition of **Pseudo-spondylolisthesis** (see p 374) is not uncommon.

In the kypho-scoliosis which is seen in some cases of tabes, lateral displacement of the vertebral bodies may be seen at the apex of the curvature. The concave aspect of the curvature is associated with much dense reactive bone on the vertebral bodies, the opposing surfaces of which appear to be somewhat woolly and lacking in sharpness of outline. Forward displacement of the upper column on the lower at the fourth or fifth lumbar junction is seen following trauma and in the condition of spondylolisthesis (see p. 306) Such dislocations in this and at other sites may be associated with congenital deformities, chondro-osteo-dystrophy and localised disease of the bones or joints. On p 382 reference has been made to the displacements which are seen in infancy

No radiographic indication of these bands can be obtained unless they have undergone calcification. In other cases a joint may be seen in the cervical rib or between its anterior extremity and the first dorsal rib. In the case published by *Billington* the cervical rib pressing on the third part of the left subclavian artery gave rise to an aneurysm.

My report on the radiograph of this case stated: "Fully developed right cervical rib. The left cervical rib is incomplete: its anterior extremity has formed a symphysis with the first rib on a plane with the clavicle. The swelling of the soft tissues is in this area."

This case illustrates the fact that while the incomplete cervical rib may give rise to symptoms, the complete cervical rib may not. Some authorities consider that the incomplete development of the rib is due to nerve pressure.

A soldier aged 30 was seen with a large first rib (see Fig. 375 D) which pressed upon the innominate vein and led to marked dilatation of the veins of the arm and side of the chest. The pressure was relieved by carrying the arm in a sling. The details of these cases are at variance with the opinion of *Jones* and *Lovett*, who state that "an apparent localised dilatation of the subclavian artery has been described many times in association with cervical ribs but true aneurysm is unknown. The subclavian vein at a lower level is in no direct relation to the rib."

Dow points out that unless the vertebræ are counted from the atlas downwards, it is difficult to decide whether or not a rudimentary rib is a cervical rib or a first thoracic rib.

The longer and more prominent transverse processes of the seventh cervical vertebra and the still longer horizontal or proximally directed transverse processes of the first dorsal vertebra are distinctive, and supply the radiologist with localising features which enable him to decide the vertebra to which the rudimentary ribs belong, the rudimentary characters of the rib having attracted his attention.

It is the close relationship of these rudimentary ribs to the nerves and vessels which produces the symptoms requiring investigation; whether it is called a cervical or dorsal rib is merely of academic interest. Diagnosis by clinical examination can be made in some cases, the rib forming a hard tumour at the root of the neck, but in many cases radiography is essential. As the pressure of these ribs on the brachial plexus produces signs and symptoms resembling those seen in some cases of Progressive Muscular Atrophy and Syringomyelia, a radiographic examination of the lower cervical area should be made in these conditions.

Le Vay has indicated that Costo-Clavicular Compression may produce similar signs. He reported a case in which the artery and plexus of a girl aged 23 were hooked forward by the first rib to which they were bound by dense inflammatory fibrous tissue. The artery was small and bore signs of recent compression. The finger could hardly be introduced into the narrow space between the rib and the clavicle in front of the artery and lower trunk and was tightly nipped when the patient was asked to brace her shoulders back—a movement which compressed artery and nerves hard against the first rib. The clavicle compresses from without inwards but it moves downward and backward, squeezing the structures against the first rib.

He shows that the scalenus may protect and its division may exacerbate symptoms. Bilateral ossicles may be seen articulating with the tips of the transverse processes of the first dorsal vertebra.

CERVICAL SPINE

Congenital Anomalies at the upper and lower extremities of the cervical spine are relatively common. Reference has been made above to cervical ribs. An excellent

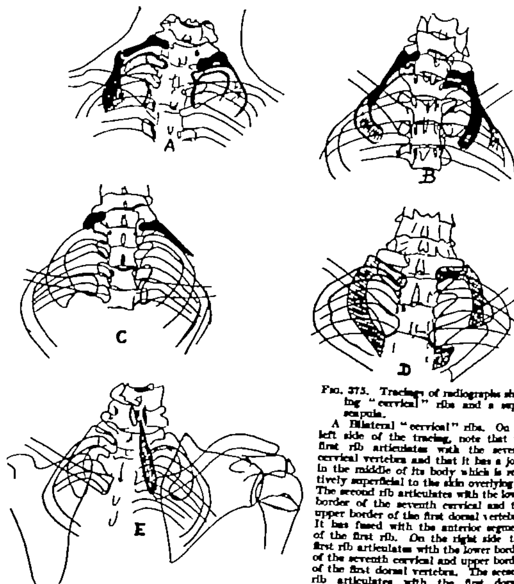


Fig. 375. Tracings of radiographs showing "cervical" ribs and a suprascapula.

A Bilateral "cervical" ribs. On the left side of the tracing, note that the first rib articulates with the seventh cervical vertebra and that it has a joint in the middle of its body which is relatively superficial to the skin overlying it. The second rib articulates with the lower border of the seventh cervical and the upper border of the first dorsal vertebra. It has fused with the anterior segment of the first rib. On the right side the first rib articulates with the lower border of the seventh cervical and upper border of the first dorsal vertebra. The second rib articulates with the first dorsal vertebra only These two ribs ha fused together just anterior to the tubercles. B Bilateral "cervical ribs. On the left side the first rib articulates with the seventh cervical body the second rib articulates with the lower border of the seventh cervical and the upper border of the first dorsal vertebræ. A false joint is made between the end of the first rib and the angle of the second rib. On the right side the first rib articulates with the seventh cervical vertebra on a lower plane than the one on the opposit side the second rib with the lower border of the seventh cervical and upper border of the first dorsal The first rib resembles a normal first rib, but the second is more slender than the normal C. Bilateral "cervical" rib. On the left side the rib is diminutiv and fused with the second rib of the tubercle. The one on the right side fuses with the second rib at the angle of the latter. D Bilateral abnormal first ribs. On the right side the first rib articulates with the first dorsal vertebra only There is failure in the ossification of the anterior extremity Opposite the angle of the second rib which bears a tubercle the first rib ossification ceases abruptly Ossification has occurred in its corresponding costal cartilage attached to the sternum. On the left side the first rib is complet It articulates with the first and second dorsal vertebræ and is united to the upper part of the sternum. This patient, a soldier aged 50, showed marked dilatation of ll the veins over the right shoulder and arm E. Right *Sprengel* shoulder The laminæ of the fifth, sixth and seventh cervical vertebræ are defective They are substituted by long spicule of bone—the supra-scapula.

Similar fractures have been seen in men who have had the head forcibly jerked back by sudden pressure applied to the chin as in falling through trees. It was seen in a workman whose head was forced by the ascent of a lift, the roof of which he was repairing from the floor above it.

Injury to the cervical discs and other conditions which bring about secondary reactive changes in the bones with resultant narrowing of the intervertebral foramina may be associated with trophic changes in the arms. *A. Oppenheimer* has reported 14 cases of symptomatic herpes zoster in association with these lesions.

Fractures of the odontoid and bodies of the cervical vertebræ may not be visible on radiographs immediately after the accident but become very evident after an interval of a month or so.

Arthritic changes with diminution of the disc space, lipping of the fifth and sixth cervical vertebral bodies, in some cases with erosion or sclerosis of approximated surfaces is a common finding in adults. It may be associated with limitation of movement and pain.

DISLOCATION OF THE CERVICAL SPINE

This may result from congenital anomalies, trauma, chondro-osteo-dystrophy and local bone disease.

Kleinhaus has drawn attention to the fact that the diagnosis of fracture dislocation of the second cervical vertebra has been made in error from radiographs taken with the neck of the patient rotated. Spontaneous dislocation of the cervical vertebræ has been seen in cases of tonsillitis, measles, and other infectious diseases of childhood (see Fig. 370). *D. Levi* has published the details of this lesion in a boy of 21 months and a girl of 5 years.



Fig. 378. Lateral radiograph of the neck showing backward dislocation of the axis following tonsillitis.

Dislocations have been recorded by *Blaine*[1] following chiropractic treatment. *Binnie* records a case of bilateral dislocation of the sixth cervical vertebra forwards.

Dislocation may be found in a patient whose odontoid has failed to ossify.

Under the title of simple uncomplicated rotary dislocation of the atlas, *R. H. Jackson* has described and illustrated a slipping forward of the articular facet of the atlas on to, or over the anterior marginal lip of the facet of the axis, following rupture of the capsular ligament of one of the atlanto-axial articulations. He says the unilateral forward displacement of the atlas can be felt. In a normal subject the transverse process of the atlas may be felt on deep palpation, with the finger midway between the mastoid process

account of the developmental anomalies of the atlas and axis which is well and plentifully illustrated is given by *P Geipel*

Fusion of the lower cervical vertebræ associated with spina bifida and similar changes in the upper dorsal vertebræ have been seen in a number of cases. This deformity results in shortening and limitation of all movements of the neck. It is sometimes associated with torticollis, asymmetry of the face, scoliosis of the dorsal spine, nystagmus lesions of the nerves for the upper extremity progressive spastic paraplegia, sphincter disturbances, neurotrophic joints, and deformity of the shoulder and upper limb bones.

Klippel and *Feil* first described the deformity in 1912, and since that date reports of many cases have been published. Familial distribution has been noted.

E C. Turner H S Shoulders and *L. D Scott* have recorded the beneficial effect of traction in a case which developed swelling, heaviness and stiffness of the left arm.

Pytel and *Schajewitsch* have reviewed some of these cases and publish radiographs illustrating the lesion.

Beaujeu and *Bloch* record the details of a girl, aged 17 years, with the *Klippel Feil* syndrome, *i.e.*, shortening of the neck, low hair line at the back, and limitation of the movements of the neck. The radiographs show synostosis of the upper cervical vertebral bodies and arches and failure of fusion of the arches of the seventh cervical and first dorsal vertebræ

Cornil has recorded a similar case which presented the signs and symptoms of progressive nerve involvement.

Diamant Berger records a congenital absence of the arch of the fourth and body of the seventh cervical vertebræ in a boy of 5

Anomalies of the atlanto-occipital area are more frequent than the lower cervical deformities. Examples of synostoses of the atlas with the occiput, the odontoid to the atlas, the atlas and axis with failure of union of the arches, defective development of the odontoid, are amongst the most common deformities which have been seen (see also p 479).

The term **Occipitalisation** of the atlas has been used to denote the first-mentioned anomaly This may be unilateral or bilateral.

Roger has recorded pareses of the hand and atrophy of the thenar eminence in association with deformities of the upper cervical vertebræ. Illustrations and descriptions of these deformities can be found in the papers published by *Geipel Gladstone* and *Wakeley R. H Hunter Ingber* and *Renander* [1]

See also Basilar Impression, p 478

Barsony and *Winkler* illustrate a number of cases of **Calcinosis Circumscripta** ligamentum nuchae. Radiographs show irregular plaques of ossification or calcification in the midline posterior to the spines of the lower cervical vertebræ more commonly the fifth. Their etiology is unknown. They are more commonly found in old people with spondylitis

Clay Shovellers Fracture. Fractures of the spinous processes with displacement of the fragments have been noted repeatedly in men working with the shovel or spade. In Western Australia the term clay shovellers fracture has been applied to such lesions because of its frequency in relief workers who are engaged in shovelling clay The history of the accident is similar in practically all cases—the labourer throws up a shovelful of clay the clay sticks to the shovel momentarily and the worker feels a sudden stab of pain and sometimes hears a crack somewhere between the shoulders and is unable to continue working The seventh cervical spine is the commonest affected but the injury may involve the sixth cervical or the first, second or third dorsal spines A good account of the condition is given by *R D McKellar Hall.*

CHAPTER XVII

THE SPINE (*continued*)

DYSTROPHIES OF THE SKELETON

Achondroplasia. The vertebral column in the infant often shows a very decided but regular kyphosis of the lower dorsal and upper lumbar vertebræ in some cases with compression of the anterior surfaces, where brought into contact at the key point of the arch. In some cases all the lumbar vertebræ are included in the kyphos (see Fig 330) bringing the sacrum into a horizontal position, *i.e* at right angles to the axis of the body The coccyx may be acutely flexed forward.

The vertebral bodies in the cervical area appear to be more massive than normal, they are deeper and more closely approximate the cube in shape. The spinous processes are as deep as they are long The discs appear to show wear at an earlier age than normal and the approximated bony surfaces become sclerosed and pressure moulding is evident. Compared to the limb bones the vertebral column shows little shortening

Graham s specimen in the museum of the anatomical department of the University of Birmingham has a vertebral column which is little shorter than the normal, but *Thurston Holland's* radiograph in *Jones* and *Lovett's* "Orthopedic Surgery" shows that all the vertebral bodies are much shorter than the normal and the spine correspondingly shorter

Chondro-osteo-dystrophy Several types of this dystrophy are met with.

Type A. Eight examples of this type have occurred in the series. One case a girl, has been under observation for 13 years and is now a dwarf aged 17 years.

The anterior-posterior radiograph shows a degree of osteoporosis with marked irregularity of the outline of the vertebral bodies which appear to be compressed to a thickness less than a third of their breadth, some of the bodies being broader than others, the broader bodies being irregularly disposed in the spine.

The extremities of the transverse processes and the heads of the ribs are splayed out and cupped. The sacro-iliac joint spaces are much wider than the normal and their borders are irregular in outline.

The lateral radiograph shows in a more striking manner the irregularity of ossification of the vertebræ. The bodies show irregularity in size, shape and position. Small bodies with irregular outline are disposed throughout the column. The shape shows a marked departure from the normal. Some appear to be shaped like a shoe facing anteriorly a segment from the upper anterior part of the body not showing evidence of ossification. The irregularity in the size of the bodies gives a striking alteration in the alignment of the anterior surface, and the normal curves of the spine are obliterated. The same curvature may be seen as in achondroplasia but it is masked by the irregular forms of the vertebral bodies. In 3 cases, backward dislocation of the first lumbar vertebra had occurred, producing a kyphos, which gave the clinical appearance of tuberculous caries. The deformity of the lumbar spine was noticed soon after birth in 2 of the cases. One of the cases died at the age of 15 he had been observed for 12 years and during that time he had not grown. This child had also a very short neck and there was a suggestion of dislocation in the lower cervical vertebræ

This is the most severe type of skeletal dystrophy It is associated with the appearance of fragmentation of all the epiphyses of the body (see Fig 377), and it is doubtful if such children reach maturity (My original patient showed progressive

and the angle of the jaw In rotary dislocation the transverse process may be plainly felt on the side from which the head is turned. On the opposite side the finger sinks in deeply and forward as the transverse process has in these cases been displaced backwards. If the left side is dislocated, the head can rotate only a little to the right, the right atlanto-axial joint is fixed and the left moves, and *vice versâ*. The chin will point to the side on which the transverse process is rotated backward.

Jackson points out that the odontoid process may be also fractured, and that this should be ascertained before attempting reduction.

Dysphagia, localised pharyngeal anaesthesia or persistent neuralgia may be present due to nerve trauma.

The lesion may not be recognised for years It may cause a compression myelitis. Radiographs of the area should be made in several planes. If owing to the displacement, it is not possible to take a radiograph of the joints through the open mouth—the view which affords the best evidence of the condition of the odontoid and the atlanto-axial joints—radiographs taken with the chin on the film, the neck being extended as far as possible and the central ray passing through the vertex, will usually afford additional evidence of the condition and position of the atlas and axis.

If the patient has a fixed rotation of the neck there is a possibility that the displacement, particularly in the region of the seventh cervical vertebra may be missed on the radiograph or that the normal may be misinterpreted Radiographs should be taken in several planes and stereoscopically

signs of achondroplasia until after an acute illness resembling rickets at 4 years of age

Type C. Examples of this type were seen in children ranging from 1 to 10 years.

The vertebræ in this type are regular in size and uniform in shape. On the antero-posterior radiograph the vertebral bodies appear to be stippled and compressed, but the compression is not so marked as in Type A.

Before the epiphyses for the upper and lower borders of the bodies appear the anterior margins are tongued, the upper and lower anterior corners do not show any evidence of ossification. In the older case the vertebral bodies show a greater degree of compression and all the surfaces except the posterior are irregular, the anterior surface showing the greatest amount of irregularity.

Both these cases showed failure of ossification of the femoral head and neck (see Fig. 273) but the only other departure from the normal of the bones of the extremities was an extra epiphysis for the second metacarpal. With this type of dystrophy the physical appearance of the patients suggests that they will live to maturity.

Type D. In this type the spine only shows irregularity of ossification. In these the vertebral bodies were irregular in shape, the first lumbar body being about half the size of the others leading to a kyphotic deformity.

Albers-Schönberg's Disease (Marble Bones). In this condition the infantile shape of the vertebræ (see Fig. 240) may persist until adolescence.

On the lateral radiograph the bodies of the vertebræ are regular in size and shape before adolescence but appear to be made up of three "segments," the upper and lower being dense and without any cancellous reticulation, while the middle segment shows relative osteoporosis with irregular reticulation. As accretions of chalky bone are added with age to the upper and lower borders the middle "segment" becomes relatively diminished.

Uniform density of the ribs and other bones occurs in association with these changes in the vertebræ.

Duncan White has shown the radiographs of the spines of two brothers who are affected with this disease, but in these the vertebræ are normal in shape and size but uniformly denser than normal.

Osteogenesis Imperfecta. The vertebral bodies show more or less compression though the disc spaces appear to be increased. This compression may be general but in some cases it is confined to the upper dorsal area, where the depth of the vertebral bodies may be less than half the normal. The compression of the bodies is also often associated with a biconcave deformity in which their superior and inferior surfaces may appear to come into contact at the mid point, *i.e.*, they assume the shape of fish vertebræ; the discs appear to be correspondingly swollen. In one case the compressed bodies presented an unusual biconcave deformity due to a disc compression in the posterior aspect of the intervertebral space.

The osseous nuclei for the superior and inferior plates were laid down in denser bone in 1 case and at the early age of 6 years.

In the adult extreme degrees of scoliosis may develop, the resulting curvature being far greater than can be attained by the trained gymnast (see Fig. 378).

The antero-posterior radiograph of a case in the series (a woman aged 30) showed a complete "S" bend of the dorsal and lumbar spine with marked rotation and accommodating deformity of the vertebræ. The vertebral bodies and processes in severe cases will show a radiographic appearance which suggests that the bones are composed of soft plastic material because they exhibit all the deformities of shape one would expect with such material.

weakness and flaccidity of the muscles and died at the age of 15 but one is still alive at the age of 17 years.)

I have never radiographed any adult patient whose bones suggested such a severe dystrophy

Type B Examples of this type were seen in boys ranging from 5 to 19 years.

The antero-posterior and lateral radiographs show that the only deformity is a general but regular compression of the vertebral bodies Radiographs of the limb bones of the eldest boy taken at the age of 9 years, showed multiple ossified nuclei for



Fig 377 Radiographs of the spine and pelvis of a boy aged 4 years, showing irregularities of the bony outline due to Type 1 chondro-osteo-dystrophy Died t the age of 15.

the epiphyses, but recent radiographs show that consolidation has occurred with evidence of pressure deformity

In the two younger patients the radiographs show a small first lumbar vertebral body and the anterior half of the body appears to be missing

This type of dystrophy after the epiphyses have consolidated, gives a radiographic appearance of the bones not unlike that seen in Achondroplasia. This may account for those cases which appear to develop achondroplasia after birth.

Lanford Kneggs [1] refers to a case described by *Emerson*. This child showed no

DISEASES OF CHILDHOOD

Infantile Rickets leads to exaggeration of the normal spinal curvature and may be associated with scoliosis The deformity is most marked in the most dependent part *i.e.*, the lumbo-sacral area The vertebræ may sink with the sacrum between the ilia until the upper bodies of the sacrum are lying horizontal the lower sacral bodies being bent acutely forward by the weight during sitting No definite irregularity of bony outline of the vertebræ can be made out. During the acute stage the bones show osteoporosis, but when the disease has been successfully treated the bones assume the density and appearance of the normal, except in those cases where the lumbo-sacral and sacral deformities of a severe degree were allowed to develop Adequate orthopædic treatment and exercises of the young rachitic child are usually rewarded by a diminution in any deformities of the spine which have arisen.

Renal Rickets. Type A. In this condition the vertebral bodies may be approximated by disorganisation or degeneration of the intervertebral discs The epiphyses for the upper and lower borders with the corresponding surfaces of the bodies may show marked irregularity as in Fig 380 The cartilaginous plates of the superior and inferior surfaces appear to degenerate and permit the nucleus pulposus to herniate to a varying degree into the cancellous tissue of the body This would probably be greater if the discs preserved their normal texture and consistency

Type B The vertebræ show marked osteoporosis and pressure deformities with absence of the detail of the fine cancellous structure of the normal.

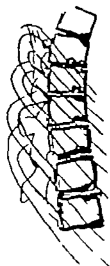


FIG 380 Tracing of radiograph showing epiphyses for the superior and inferior rims of the vertebræ, associated with narrowing of the intervertebral space and herniation of the disc into the vertebral bodies. Case of renal rickets, Type A.

Juvenile Osteoporosis of the Spine. Osteoporosis of the spine unaccompanied by similar changes in the other bones of the skeleton, or definite disease of the spine, is rare. An example of such a condition was seen in a boy 13 years of age, complaining of weakness of the back. The lateral radiograph of the spine showed a very striking picture of osteoporosis. With the exception of the anterior borders of the bodies the outlines of the vertebræ were clearly defined the upper and lower margins of the bodies, including all the sacral vertebræ, cast relatively denser linear shadows which were about $\frac{1}{16}$ inch thick not the slightest trace of structure could be seen within these bodies, and it was only just possible to distinguish the anterior surface of the bodies by their slightly greater density The vertebral bodies were markedly biconcave in shape The inter vertebral discs were swollen and appeared to be half as deep again as the mid-depth of the vertebral bodies.

The spinous processes and articular facets showed similar outlining with lack of internal structure.

The antero-posterior radiograph showed a decrease in the depth of the vertebral bodies. The transverse processes were long and slender in form. The ribs were also slender

This patient was seen again 7 years later and the radiographs showed the same appearances except for a slight increase in the density of the vertebræ

Radiographs of the pelvis and limb bones do not show any recognisable departure from the normal. There is no evidence of past or present rickets, and *none of the* deformities of osteomalacia, osteogenesis imperfecta or osteitis fibrosa cystica.

Multiple Chondromata. The margins of the growth surfaces of the vertebræ may *in early life show defects in which later densely calcified islands may appear*

Progressive Myositis Ossificans. In the infant little deformity of the vertebral column is to be made out. As early as the first year it may be possible to demonstrate narrow irregular band-like bone shadows running longitudinally in the muscles of the



Fig. 378. Antero-posterior radiograph of the spine showing marked scoliosis with structural adaptation of the vertebræ to the abnormal position. Osteogenesis imperfecta.



Fig. 379 Antero-posterior radiograph of a girl aged 16, showing irregular bands of ossified tissue uniting the lumbar vertebræ and articulating with the crest of the ilium on one side. A similar spike of ossified tissue is shown in the pelvis. Case of progressive myositis ossificans.

back Similar bony shadows may be seen between the ribs and in the limbs. With advancing age these irregular bands of ossified tissue increase, and in the case of the spine may lead to scoliosis of a severe degree and marked limitation of movement.

In the case of a girl aged 16, a radiograph of whose spine is shown in Fig 379 irregular bands of ossified tissue unite all the lumbar vertebræ and send out branches which form false joints with the iliac crests The concomitant deformity of the bones of the thumb and big toe (see Fig 125 G) should be of great help in prognosis.

Mather has illustrated a case showing extreme deformity of the bony thorax in an adult affected with this disorder

Two excellent whole skeletons of this condition are preserved in the Anatomy Department of Trinity College, Dublin *They show fusion of the cervical vertebræ with* the occipital bone and bony bands uniting these bones.

changes may develop in the opposing bony surfaces with lipping of the margins. A number of these features have been seen in the spine in cases of Type A Renal Rickets and Chondro-osteo-dystrophy the details of which are dealt with under these headings. It has been suggested by *F. H. Kemp and D. Wilson* that these changes may be due to the absorption of fluorine from drinking water.

On the antero-posterior radiograph the affected bodies in the dorso-lumbar area in the early stages may show fragmentation of the epiphyses, and, later the affected bodies appear to be splayed out beyond the line of the normal bodies. The lateral extremities of these splayed bodies are pointed, an appearance which may be interpreted as evidence of arthritis. Running alongside the lateral borders of the vertebræ in the affected area is a vertical line which marks the boundary of dense paravertebral structures with the radio-transparent lung at its postero-medial border. This line bridges the concavities of the vertebral bodies and its lateral border may show a slight convexity at the level of the splayed ends of the bodies. Some authorities have suggested that it is due to tuberculous infiltration of the tissue surrounding the affected vertebra or disc, but in tuberculous infection of the spine the lateral border of the paravertebral shadow seen on the antero-posterior radiograph, shows a definite deflection from the affected bodies, ultimately assuming the characteristic spindle-shape of a paravertebral abscess as shown in Fig. 408. Such a deflection of the line does not occur in osteochondritis. Though kyphosis is the usual feature, degrees of scoliosis are also seen.

Radiographs illustrating the appearance of this condition are to be seen in the papers published by *Scheuermann, Buckmann*,[1] *Harbin* and *Zollinger, Weiss*,[1] *Junghanns, Schinz*, and *Boorstein*.[1]

Boorstein[1] illustrates a condition which he calls osteochondritis, but which shows a much greater deformity of the vertebral body than is commonly seen in this condition. His patient was a child 4 years of age. The radiograph shows a marked reduction in the size of the third lumbar body which appears as a small wedge of bone with the posterior extremity of the wedge directed toward the spinal canal. The vertebral bodies above and below have not encroached upon the discs or the space caused by apparent shrinkage of the affected vertebra.

This deformity may have followed destruction of the cancellous structure of the vertebra by trauma.

The author radiographed a baby 2 weeks old to ascertain the cause of a kyphos of the dorso-lumbar area. This radiograph showed complete absorption of the bodies of the twelfth dorsal and first lumbar vertebræ and an appearance suggestive of erosion of the upper border of the second lumbar body. The diagnosis of tuberculosis or syphilis was tentatively made though no evidence of abscess was seen clinically or radiographically. The patient was put on a frame and further radiographs were taken every year until he was 6 years of age. These radiographs show that the upper border of the second lumbar body has reformed, but no repair is to be seen in the twelfth dorsal or first lumbar vertebræ. The space caused by the destruction of the bodies is partly filled in by angulation of the spine at this level. A small detached fragment of bone is shown just anterior to the lower border of the eleventh dorsal body. Clinically there is no evidence of inflammation, and one is considering the possibility that this appearance is due to trauma at birth, producing the changes seen in some cases of Osteochondritis.

Vertebra Plana. This deformity of the vertebral body was first described by *Calvé*. The radiographs show uniform compression and condensation of the affected vertebral body. It may appear to be reduced to 1 mm. in depth. It is denser than the normal vertebral body. The adjacent discs above and below appear to be unaffected, they preserve their depth, but owing to the loss of depth in the affected body the adjacent

The ætiology of the condition is unknown.

The appearance of the spine in this case resembles the appearance seen in Senile Osteoporosis so well illustrated by *Junghanns*

Polgar has described a case of presenile osteoporosis with radiographs showing flattening and biconcave deformity of the vertebral bodies

Osteochondritis of the Spine. Osteochondritis of the spine is seen at the same age period as osteochondritis deformans juvenilis coxæ.

The condition was described by *Scheuermann* as Kyphosis Dorsalis Juvenilis in 1921

It is usually associated with a general exaggeration of the dorsal curvature, which, untreated, ultimately results in a wedge-shaped deformity of the vertebral bodies and diminution of the intervertebral discs The dorso-lumbar area is the commonest site for the development of the lesion but lesions may be found above and below this area.

The condition occurs more frequently in rapidly growing girls. Though in some cases it appears to commence before the child is 10 years of age, the majority of girls are aged 12–13 years and the boys 15–16 years when treatment is first sought for a marked dorsal kyphos and stiffness of the back It does not appear to be due to lack of muscular tone for this appears to be normal No distinctive laboratory findings have been made. In some cases there may be a history of trauma. In debilitated children particularly in those affected with chronic bronchitis or other pulmonary disease, the normal posture is not maintained and the periodical physiological reshuffling of the musculature, ligaments and bones is not performed. As a result the curvatures are increased—particularly the dorsal and the dorso-lumbar This puts abnormal prolonged strain, particularly on the structures at the apices of the curvatures progressive pressure deformities of the bodies develop and the ossification of the epiphyses becomes irregular so that the exaggerated curvatures eventually become fixed (see Fig 345). In the early stages pain is often a feature, but this may be regarded as "growing pain." It may be taken as a family trait for several members, a parent and one or more children, may exhibit a kyphos. As with all cases of osteochondritis, recumbent treatment of the early condition before the plastic vertebral bodies have been compressed offers the best chance of return to normality Once the bone has been compressed the deformity cannot be corrected and with the stresses and strains of adult life the anterior surfaces, particularly in the region of the apex of the curvature, will be brought into contact. Reactive sclerosis of the bone and ossification of the ligaments will result.

The lateral radiograph shows an appearance of the upper and less commonly of the lower borders of the vertebral bodies resembling that of osteochondritis in other sites. The epiphyses may show an added density and later fragmentation Fragments may be displaced These appearances are associated with widening of the metaphyseal area, *i.e.* area of transparency between the epiphyses and the body The body itself where it borders on these metaphyses may appear to be splayed out by pressure indicating softening of the bone, and it may give an indication of the furrows seen in this situation in the macerated specimen. An indentation may also be shown into the mid-area of the upper or lower borders of the vertebral body due to herniation of the nucleus pulposus through the cartilaginous plate of the intervertebral disc. No encroachment on the depth of the intervertebral space is seen at this stage.

A number of these lesions of the nucleus pulposus, which were first described by *Schmorl*, may be seen in the dorsal or lumbar vertebræ with or without the obvious changes in the vertebral bodies above described.

The destructive process may ultimately involve a considerable amount of the vertebral body With consolidation of the involved vertebræ the intervertebral space may be diminished and the bodies so closely approximated that secondary arthritic

Uniform compression of several isolated vertebral bodies has been seen by the author in cases which presented the typical map-like appearance of lipoid dystrophy on radiographs of the skull (see also pp 035–" and Fig 482)

In 3 cases seen by the author in boys at the age of 2 11 and 12 the patients were brought for radiographic examination because of localised kyphos with pain in the back in the two older children radiographs show slight general rarefaction of a body with a surrounding small paravertebral " abscess which led to the suspicion of tuberculosis in the first case. After an interval of 3 months, in the boy of 12, further radiographs showed that the affected vertebral body was flattened out and the fusiform paravertebral shadow had disappeared. There was no sign of any diminution of the disc spaces.

The most interesting and instructive case of this condition which has been published is that of *Fawcitt* His patient, a girl of 4 years of age, began, early in December 1938, to complain of increasing pain in the region of the lumbar spine, which was accompanied by loss of appetite and weight. Radiographs January 27th, 1938 showed but a linear shadow of the third lumbar vertebral body which appeared to be irregularly decalcified. The pedicles also were markedly decalcified but the disc spaces above and below were of normal depth. The lumbar lordosis was abolished and muscle spasm restricted movements Von Pirquet reaction was negative to human and bovine strains. She was put on a spinal support and kept flat. All the symptoms soon ceased By 17/5/38 the pedicles showed recalcification and the flattened body more than the average density the shadow of a stone had now appeared in the left kidney The density of the compressed body increased during the next 3 months and by 15/8/39 had acquired its maximum density but now a large area of decalcification was seen in the head and neck of the right femur Towards the end of September the child complained of abdominal pain and vomiting and she had an intermittent pyrexia. 17/10/38 both kidneys now showed stones and the third lumbar body showed a peripheral zone suggesting early regeneration. Towards the end of November there was a return of the pain on the right side frequency of micturition with hyperpyrexia. There was pus in the urine In January 1939 the lesions in the right femoral neck were more clearly defined. 22/4/39 the patient fell and hurt the left arm. A radiograph showed a large area of decalcification involving most of the upper third of the humeral diaphysis through which a fracture had occurred. On January 20th, 1940 radiographs showed that the humerus had returned to its normal density and the lesions in the femur were clearly defined. 15/6/39 the skull showed some irregular decalcification in the parietal and occipital bones—the body of the axis appeared compressed and dense. Well-defined areas of cancellous destruction were at this time seen in the ilium.

20/0/39 the compressed and elongated third lumbar vertebra had returned to normal texture, but now the fourth lumbar body was compressed to half its depth and it had acquired density

17/8/39 much of the central dense nucleus of the third lumbar body has been absorbed and there is a suggestion of slight rarefaction of the fourth body which is still of normal shape but on 20/9/39 the latter is compressed and elongated but not showing the same density as was noted in the third, and on 20/12/39 both bodies appear to have been reconstituted though remaining compressed and elongated. This remarkable case of multiple areas of decalcification which in the vertebra led to the sequence of radiographic changes seen in Köhler's disease of the tarsal scaphoid was associated with the development of stones in the kidney but no light was thrown on its pathology Temporary endocrine disturbance was suggested by Finzi The changes in the bones are certainly not those of simple avascular necrosis as indicated early in this chapter

bodies may show some inclination towards each other anteriorly and a slight kyphos may develop The aetiology of the condition has not been clearly described It has been regarded as an osteochondritis and as flattening may occur in any condition which destroys the integrity or produces plasticity of a localised body or bodies without destroying the adjacent disc, it has been described in association with various pathological conditions Probably the most common cause for the typical lesion described by *Calvé* is



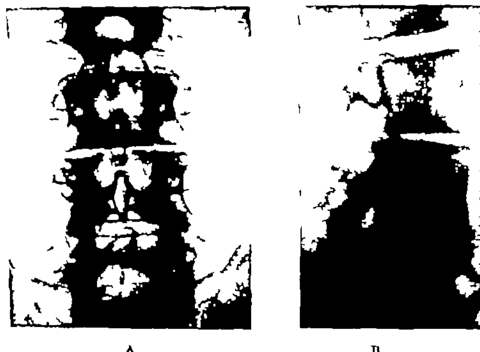
FIG. 381A. Fracture of seventh dorsal body 28 days after injury (2/7/46).

FIG. 381B. Same patient (19/1/47) showing typical vertebra plana.

trauma The author watched its development in the case illustrated by Fig 381 This boy fell 6 feet, injured his back by striking it against some steps. As the pain persisted he was brought to hospital 4 weeks after and a radiograph showed some wedge-shaped compression of the eighth dorsal vertebral body which was of diminished density The compression continued and within 3 months the affected body had been reduced to linear dimensions but had an increased density Anteriorly it was compressed beyond the line of the surfaces of the vertebra above and below *A F Massaro* has given an illustrated account of a boy aged 3 years with a similar lesion in the second lumbar vertebra. After 4 years there was evidence of normal bone growth around the condensed nucleus and after 11 years regeneration was so complete that little evidence remained that the body had been affected (see also Osteomyelitis of Spine " p 440).

posterior half of the disc, and the bowl the nucleus pulposus. The depth of the vertebral body is correspondingly reduced in its anterior half

The radiographs of the lumbar spine in flexion and extension particularly in the sitting position and when erect show a slight forward projection of the lower body in flexion, but the position is corrected in extension. This has been regarded as evidence of instability of the disc, for when there are other signs of disc degeneration, *i.e.*, narrowing of the intervertebral space, reaction in approximated surfaces the forward displacement in flexion is more marked *Knutsson* has shown [1] that vacuum phenomena can be demonstrated in the discs The radiographs show a streak of radio-transparency in the centre of the disc when the spine is hyperextended It



A B

Fig 882, A and B. Atrophy of intervertebral disc between the third and fourth lumbar vertebral bodies due to needling (lumbar puncture).

disappears on flexion. He regards it as pathognomic of disc degeneration and due to the expulsion of gases in solution in synovial fluid on reduction of pressure. It resembles the appearance seen in certain joints on hypertension. The instability associated with disc degeneration or spondylolysis in the lumbar spine has been demonstrated by *Knutsson* [2] by taking radiographs with full extension and flexion of the trunk with the patient standing

Atrophy and degeneration of the discs in the cervical spine becomes associated with reduction in the disc spaces, loss or reversal of the normal cervical curvature, reactive sclerosis or erosion of the approximated bony surfaces with osteophytic out growth at the borders. It is most common in the fifth and sixth vertebræ.

Destruction of a localised disc without any appreciable changes in the adjacent

Similar changes have been seen in cases with disturbance of lipoid metabolism. The case of Gaucher's disease, described by *Buston*, is interesting in this respect. His patient was a girl of 5 years 11 months. Splenectomy was performed and after this she had an attack of pneumonia. She had a history of osteomyelitis 3 years previously. Radiographs now showed a complete collapse of the ninth dorsal vertebral body with some degree of osteoporosis of the others.

The cases of Hodgkin's disease, described and illustrated by *Blount* and by *Hähn*, presented compression deformities of several vertebral bodies (see p. 451).

See also *G. Jansson's* case of xanthomatosis, p. 400.

Panner[1] records a case with a radiograph showing the typical appearance. The patient was a man of 22 years of age, apparently quite healthy, who had a kyphotic deformity at the level of the eighth and ninth dorsal spines. There was no history of trauma.

It is to be assumed that the condition is allied to osteochondritis. Similar appearances have been illustrated by *Harrenstein*, *Hansen*, *Jansen*, *Polgar* and *Schrader*.

THE INTERVERTEBRAL DISCS

The intervertebral discs are composed of three essential structures, the nucleus pulposus, the annulus fibrosus, and the cartilaginous plates of the adjacent vertebræ.

The discs show a variation in shape in the different segments of the spine. They are thickest and best developed in the lumbar region and thinnest in the thoracic. In the thoracic region they are flat, but in the cervical and lumbar areas they are wedge-shaped because of the forward curvature in these areas, the greatest depth being anteriorly. The nucleus pulposus is a semi-fluid myxomatous remnant of the notochord, which occupies a central or slightly posterior position in the disc. It is kept in position by the annulus and the cartilaginous plates. Being of a semi-fluid nature, situated within a structure which permits of a certain amount of movement and compression, it acts as a buffer or shock absorber.

The nucleus is under a certain amount of pressure due to the weight of the trunk and its own bulk in a somewhat elastic casing.

It therefore exhibits the elasticity of a spring and the movements of a ball joint.

The annulus fibrosus is made of complicated concentric lamellations of fibro-cartilage which are firmly attached to the adjacent borders of the vertebral bodies by strong fibres.

The cartilaginous plates cover the sieve-like surface of the cancellous bone of the vertebral body, and are united around the borders to the epiphyseal circumferential plates. In the lower animals the entire upper and lower cancellous surfaces of the vertebral body are covered by epiphyses of compact bone having a smooth intervertebral surface.

Lesions of the Discs. In osteoporosis the cancellous structure of the vertebral bodies yields to the pressure of the nucleus pulposus, and the bodies become markedly biconcave in shape with a corresponding biconvex swelling of the discs. Such deformities are therefore seen in osteomalacia, osteogenesis imperfecta, hyperparathyroidism, osteitis deformans, lymphadenoma of bone and certain cases of metastatic carcinoma (see Fig. 411).

In the lower dorsal spinal caries of children an exaggeration of the lumbar lordosis occurs and the nucleus appears to be displaced to the anterior aspect of the disc, for the intervertebral space is of the shape of a wine-glass, in which the stem represents the

As illustrated in Fig 383 A damage to the intervertebral disc results in approximation of the adjacent vertebral bodies and reactive sclerosis of their opposing surfaces with splaying out of their borders and sometimes localised ossification of the intervertebral ligaments. But though in this case lipiodol showed the deformity illustrated in Fig 383 B no lesion could be detected by the surgeon on exploration

Any condition which breaks the continuity of the cartilaginous plates or breaks the annulus from its moorings will permit of displacement of the semi-fluid nucleus pulposus. In certain conditions such as juvenile kyphosis, damage to the cartilaginous plates leads to endochondral growth which appears to burrow into the cancellous structure of the body These nodular protrusions of cartilage (*Schmorl's* nodes) do not often ossify Their shape varies in different vertebræ some being described as of strawberry raspberry or caterpillar shape *Schmorl* reported prolapse of the nucleus pulposus into the vertebral bodies in 35 per cent. of 3,000 spines which he examined He stated that the lesion was probably due to overstretching of the cartilage plates in young people



FIG. 383B. Radiograph showing deformity of the lipiodol column opposite the lumbo-sacral disc.

These nodes are best seen on lateral radiographs of the spine but in some they can be well shown on the antero-posterior radiograph. They appear as indentations into the vertebral body from the disc surface near the mid-line, but generally rather nearer the posterior surface of the affected body Corresponding indentations of opposing surfaces may be present throughout a large part of the spine. In older patients condensation of the bony walls of these protrusions may be seen (see Figs 384 B and C)

In renal rickets they appear just posterior to the anterior rim of the epiphysis

Junghanns illustrates cases in which persisting notochordal tissue is continuous through the entire depth of a vertebral body in one case through the middle of the body in another through the posterior extremity of the body

Following herniation of the disc into the vertebral body calcification may occur in it, and this gives a radiographic appearance which may be simulated by tuberculous caries with rarefaction of the body localised central erosion and an amorphous sequestrum within the focus of diseased bone These conditions are illustrated in Fig 384 D

Fig 384 B is a tracing from the radiograph of a youth, aged 19 who exhibited a localised kyphosis at the level of the affected vertebræ The lateral radiograph shows hernial protrusion of the discs into the inferior surfaces of the eighth and ninth dorsal

vertebral bodies and in the acute stage associated with a paravertebral shadow may ultimately result in complete fusion of the approximated bodies This has been seen in paratyphoid and undulant fever

Atrophy of the discs in the dorsal area associated with an increase in the curvature is indicated on the radiograph as a diminution of the intervertebral spaces often with some slight pointing of the anterior borders of the bodies and small triangular-shaped calcifications in the gaps between the beaked surfaces

The most remarkable, and perhaps typical, generalised degeneration calcification



FIG. 383A. Radiograph showing diminution of disc space with lipping and sclerosis of approximated body surfaces.

and ossification of the discs in association with similar changes and osteophytic growth in the large joints may be seen in cases of alcaptonuria (see Figs. 484 A and B).

The disc may be damaged during intraspinal injections made for diagnosis or treatment (see Figs. 362 A and B) The disc space is reduced and changes develop in the approximated bony surfaces. *R. H Billington*, in recording the details of 35 cases of spondylitis following cerebro-spinal fever pointed out the fact that these patients had had several punctures which were probably responsible for destructive lesions in the discs *C A Pease* made a further communication illustrating diminution of the disc space and reaction in the approximated bodies.

nodules were found protruding into the canal from the posterior surfaces of the discs One patient complained of lumbo-sacral pain on the left side, and, later sphincter motor and sensory disturbances. The lesion was localised by radiographs after the injection of lipiodol into the spinal canal. This oil was held up at the lumbo-sacral junction. Removal of the nodule was followed by rapid and complete recovery

The other patient had complained of sciatica for 3 years, at the end of which time sphincter and motor disturbances developed No abnormality was shown on radiographic examination but a cartilaginous node was discovered at operation on the posterior aspect of the disc between the third and fourth lumbar vertebræ

They analyse 21 cases which have appeared in the literature, 10 in the cervical, 8 in the dorsal, and 7 in the lumbar areas. The lesion was lateral to the mid line in nearly all cases.

Trophic changes in the joints of the foot following the development of such a node in the lumbar area of a patient were seen by the author

Because of the phenomenal success which attended the surgical removal of some of these protrusions, and many more can be added to the early cases cited above, they were being accredited by enthusiasts with causing many of the aches and pains of the back and lower extremities, though *Beadle* had reported in 1931 " that these projections (15·2 per cent. of 308 cases) occur most frequently in the lumbar region and are really prolapses of the whole discs, but they do not project far enough to cause clinical symptoms."

In a recent paper *Inman* and *Saunders* recorded, It is disappointing however in spite of initial brilliant post-operative results, to find a certain proportion of cases presenting a residuum of painful symptoms. It is now realised that selected cases exhibiting no motor involvement, but in which a disc protrusion or herniation is demonstrable will improve almost completely with a purely conservative regimen " They emphasise the fact that a ruptured disc is accompanied by a similar injury to the ligaments around the interpeduncular foramen which is not modified by removal of the disc remnants, and in support of this they quote that the State Corporation Insurance Fund of California reports " compensable disability in 100 per cent. of patients operated upon for disc injuries.

The distribution of these protrusions has been stated to be cervical 50 per cent lumbar 35 per cent., thoracic 15 per cent.

Though trauma is regarded as the inciting cause for these disc prolapses, the histories of many of these cases do not contain details of injuries such as one would think likely to damage the disc so much. In a number of such cases manipulation of the spine preceded investigation of the canal—the trauma produced during such an operation might well be regarded as the cause for the damaged disc and as the patient had the pains previously and was not relieved by the manipulation, its success after removal of the projecting nodule can hardly be expected to be permanent.

On the other hand, investigation of the spinal canal with lipiodol which leads to the discovery of complete blocking or considerable distortion is a very valuable contribution to the treatment of the case for surgical removal of simple tumours has resulted in the complete cure of patients with very disabling symptoms In some cases prior to the radiographic demonstration the progressive lesions had been regarded as intrinsic disease of the central nervous system for which no cure could be expected.

The study of the monograph " La Hernie Posterieure, by *P Glorieux* is recommended

Epstein has recorded three cases in which low back pain was associated with varices of the epidural veins which simulated herniation of the nucleus pulposus The signs

vertebral bodies and a similar but smaller lesion of the sixth dorsal. Within the excavations of the bodies an irregular dense calcified body is shown.

Following trauma which ruptures the cartilaginous plate, the nucleus *pulposus* may be compressed into the vertebral body during the process of repair unless the case is treated by hyperextension. In some cases injury to a disc results in its atrophy and ossification of the common ligaments with approximation of the adjacent vertebral bodies.

Fig. 356 which is a photograph of a specimen of spondylolisthesis, shows dislocation of the disc into the spinal canal.

Following injury the posterior surface of the annulus may be pressed into the spinal canal by the nucleus pulposus and lead to pressure symptoms of the cord.

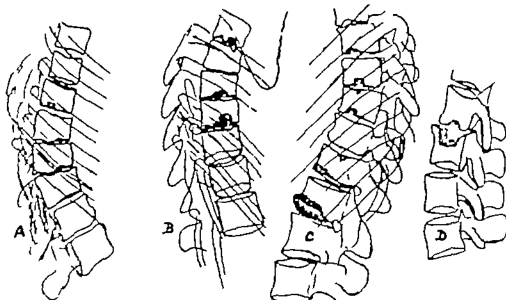


Fig. 361. Tracings of radiographs illustrating lesions of the discs and vertebral bodies.

A. Juvenile kyphosis. Note the narrowing of the intervertebral spaces between the lower dorsal vertebral bodies and the *Schmorl's* node on the inferior surface of the third body.
B. Osteochondritis of the dorsal spine. Note the irregularity of the inferior surface of the highest, the third and the fourth vertebral bodies in the tracing. The appearance of the fourth body suggests herniation of the nucleus pulposus with subsequent calcification.
C. Osteochondritis of the dorsal spine. Note the *Schmorl's* nodes in the upper bodies and the appearance of fragmentation and compression of the lower bodies.
D. Erosion of the adjacent surfaces of the upper two lumbar vertebral bodies with a central sequestrum and narrowing of the disc space. Tuberculous caries simulating *Schmorl's* nodes.

Junghagen[1] describes a case of spondylitis with neural symptoms, in which the latter were caused by the ingrowth of exostoses into the spinal canal. The deformity of the canal is shown in the radiographs after lipiodol injection. The canal is so narrowed at the level of the discs that it has the appearance of a string of beads.

Dandy describes a loose cartilage from the intervertebral disc which protruded into the spinal canal and produced symptoms suggestive of a spinal cord tumour.

Schmorl has described cartilaginous nodes on the posterior surface of the intervertebral discs caused by proliferation of the nucleus pulposus due to injury to the cartilaginous plates.

Alajouanine and *Petit Dutaillis* have given particulars of 2 cases which showed the clinical signs of compression of the cord and nerve roots. Fibro-cartilaginous

an injury Atrophy and calcification of the discs with changes in the approximated body surfaces occurs in alcaptonuria (see Figs 481 A and B p 609)

Pressure Erosion of the Vertebral Bodies. Erosion of the vertebral bodies has been seen as the result of pressure from an **Aneurysm, Paravertebral Abscess Hydatid Cyst, Tumours of the Spinal Meninges** including the so-called **Intrathoracic Neurinomata, Mediastinal Tumours,** including **Lymphadenomata** and **Sarcomata** of the paravertebral tissues. Radiographs illustrating such erosions will be seen in papers previously published by the author [2,8,13]

These bony lesions are best shown on the lateral radiograph and may be missed if an antero-posterior radiograph only is taken.

Thus in a case of aneurysm of the abdominal aorta which produced a remarkable and very extensive erosion of the bodies of several lumbar vertebræ (see Fig 380), the erosion had been missed on antero-posterior radiographs taken at intervals during the preceding 2 years to ascertain the cause of persistent and intractable pain in the back On the antero-posterior radiograph the lateral extremities of the eroded vertebræ were splayed out and pointed on the left side, but on the right side ossified ligaments bridged the discs and united adjacent vertebræ This led to the erroneous diagnosis of arthritis. Lateral to the bodies of the ninth, tenth, eleventh and twelfth dorsal vertebræ the shadows of the paravertebral structures were deflected laterally more on the left side than the right producing an appearance which simulated a tuberculous paravertebral abscess.



Fig 380. Lateral radiograph of the lumbar spine showing erosion of the vertebral bodies by an aneurysm of the abdominal aorta Note that the discs and the bones adjacent to them are not involved.

Scalloping of the anterior surface of the vertebral body is the first indication of pressure absorption. This process continues until a deep excavation is made into the bone The intervertebral discs and the bone immediately in contact with them are not involved, as a rule until very considerable erosion of the vertebral body has been produced.

If the process is slow some sclerosis of the remaining bone may be seen *Schmorl* and *Junghanns* illustrate the radiographic and photographic appearance of a dissected specimen showing aneurysmal erosion.

Fusion of the anterior surfaces of the dorsal vertebral bodies at the level of the aortic arch has been recorded by *Neuhauser* in cases of right posterior aortic arch

Some difficulty in interpretation of the radiographic appearances may occur when the amount of erosion is small and it is first discovered by radiography following trauma. Radiographs were submitted to the author of a patient aged 31 years, a pilot, who had jumped 8 feet thinking the height was but 4 feet. A fortnight later he complained to the surgeon of pain in the back. The radiograph showed slight scalloping of the ninth and tenth dorsal vertebræ—a double contour to the scalloped margin being shown in the tenth vertebral body The adjacent margins of these vertebræ were thinned and a fissure could be detected through the upper lip of the tenth. Both vertebræ were

symptoms and the spinal canal deformities were indistinguishable Decompression relieved the symptoms

In a boy aged 7 years the author accidentally found a calcified body running the whole breadth and depth of the disc space between the posterior one third of the eleventh and twelfth dorsal vertebra. There were no localising physical signs and no history of trauma. No change had occurred in the calcified mass after 4 years. In children localised deposits of calcium in this area may be associated with severe local backache, muscle spasm and restriction of movement. There may be fever and malaise as in influenza and this calcium may be gradually absorbed Localised destruction of a disc has been seen after "influenza" with approximation of the vertebral bodies and ultimately traumatic changes due to absence of the disc, sclerosis of the adjacent surfaces with lipping of the margins The dense calcium deposits in these isolated discs suggest localised necrosis following infection, toxin or trauma—the necrotic tissue having a chemical affinity for calcium (see Fig 385)



FIG 385 Degeneration and calcification in dorsal discs.

Caries of the vertebral bodies commonly begins near the disc surface and the diminution of the intervertebral space indicates early destruction of the disc In those cases of tuberculous caries associated with large paravertebral abscesses multiple bodies may show erosive scalloping of the anterior surfaces, but the intervertebral disc spaces appear to remain intact, though in some cases the nucleus pulposus in the discs between all the involved bodies may show dense calcification

O Sandström reviews the radiographic findings in 20 cases of undulant fever which had destruction of the discs

In spondylitis due to pneumococcal, staphylococcal or the typhoid group of organisms, destruction of the disc may precede fusion of the vertebral bodies, whereas in the condition of coxa plana the vertebral body is destroyed but the disc remains intact

S I S Malkin has published the radiographs with details of the clinical history of a case of infection of the lumbar spine which resulted in the fusion of the upper four lumbar bodies and a general lumbar kyphosis If the inflammatory process which destroys the disc and leads to fusion occurs in early life it may be difficult at a later age to distinguish between it and a congenital fusion

Vicotra[8] is of the opinion that the intervertebral discs may undergo necrosis and subsequent calcification a the result of influenza He terms the condition as Infective Chondro-neuritis and is under the impression that many forms of radiculitis may be due to this process

In *Barron's* case a boy of 12 a deposit of lime was shown in the discs between the twelfth dorsal and first and second lumbar vertebræ on the eighteenth day following

A patient, a man aged 46 who came under the author's observation because of a persistent pain in the back showed a localised erosion of the right side of the body of the seventh dorsal vertebra with a small opacity to the right of the mediastinum. A malignant tumour was diagnosed. Radiographs taken at intervals showed gradual increase in the erosion and involvement of the adjoining rib extremities and some increase in the mediastinal shadow At autopsy an hour-glass tumour was found which was reported as malignant.

Hour-glass or dumb-bell-shaped tumours in association with the spinal canal are



FIG. 388. Erosion of lateral aspect of dorsal body with widening of adjacent rib space due to hour-glass neurofibroma.

most frequently neurofibromata. These may be single or multiple, as in von Recklinghausen's neurofibromatosis ganglioneuromata, meningiomata and hæmangio-endotheliomata may also show this type of development. They may be found at all ages. The most important feature about these tumours is that they may show extensions (1) within the spinal canal, (2) in the paravertebral tissues, pushing antero-laterally the postero-medial border of the lung or the sheath of the psoas, and (3) between the posterior spinal muscles. Any one of these may produce signs or symptoms and unless the other possible extensions are appreciated they may be missed, until at a later date their pressure produces symptoms. Most commonly the tumour within the canal first produces signs and symptoms though, because it is confined it grows less rapidly and extensively than the others. Antero-posterior lateral and oblique radiographs may show pressure erosion of the posterior aspect of the body increase in the interpeduncular measurement, due to pressure absorption of the medial convex surfaces of the pedicles

included in a paravertebral shadow. I suggested that the erosion was due to an aneurysm, the fissure due to the [illegible] and the paravertebral shadow produced by a hæmatoma. The diagnosis was later confirmed.

Lateral radiographs of the spine in cases of calcification of the arteries may show the outline of calcified segments of the abdominal aorta. These appear as irregular shadows having a posterior border parallel to and about a quarter of an inch from the shadow of the anterior surface of the upper lumbar vertebræ.

The paravertebral abscess, which commonly accompanies spinal caries, may spread up and down over the surface of the vertebral bodies displacing the postero-medial border of the lung and becoming visible as a fusiform opacity. Within this abscess,



Fig. 887. Hydatid cyst which eroded into spinal canal.

which may involve one or two or even the whole of the dorsal and lumbar vertebræ the anterior surfaces of the bodies may show with or without calcification of the nucleus pulposus.

A case was recorded by the author of cyst of the led to erosion of the bodies of the upper d and eventually into the spinal canal (see Fig. 887).

Tumours of the meninges sometimes nerve roots of the posterior mediastinum. These tum have an paravertebral ent connected by an gh the nerve are someti r-glass tumours. variable rad ances. The of their presence ing of one the presence of ow projecting al site. Erosion of the and the oppos ay be tage (see Fig. 888).

shadow of the new growth (5) sinking together of involved vertebræ He says these changes can be produced by Primary Fibroblastoma, Sarcoma Lipoma, Neurofibroma, Osteoma Secondary Sarcoma, Chondroma, Chordoma, Ganglion Neuroma,



FIG. 390. Erosion of head and neck of rib due to malignant tumour

Hydatid Cyst, Metastatic Carcinoma, Lymphosarcoma, Hypernephroma, Myeloma, Lymphadenoma.

K Eden has given a good description with illustrations of a number of these hour-glass or dumb-bell tumours.

Pressure erosion denoted by scalloping of the surface (see Fig 388) is to be distinguished from the destructive erosion which characterises malignant growth (see Fig 390)

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FIG. 887 Hydatid cyst which eroded into spinal canal.

which may involve one or two or even the whole of the dorsal and lumbar vertebræ the anterior surfaces of the bodies may show deep scalloping with or without calcification of the nucleus pulposus.

A case was recorded by the author [32] of a hydatid cyst of the mediastinum which led to erosion of the bodies of the upper dorsal vertebræ and eventually ruptured into the spinal canal (see Fig 887).

Tumours of the meninges sometimes grow along the nerve roots into the tissues of the posterior mediastinum. These tumours therefore have an intraspinal and a paravertebral development connected by an isthmus through the nerve canal, and hence are sometimes called hour-glass tumours. They produce variable radiographic appearances. The only indication of their presence may be widening of one rib space and the presence of a rounded shadow projecting from the mediastinal shadow at this site Erosion of the vertebral body and the opposing rib surfaces may be seen at a later stage (see Fig 888).

the interstices of the cancellous mesh have been packed with calcium, obliterating its detail, whereas in the osteoporotic type all calcium available has been abstracted, leaving a cleared bone with the detail of its bigger pattern of cancellous tissue now clearly visible. These changes in the vertebræ are associated with some general increase in their dimensions—most noticeable in the transverse diameters of the bodies for these acquire a greater amount of plasticity and become more or less compressed by the superincumbent weight. This may be better indicated on lateral radiographs. The disease shows peculiarities in its distribution and extension. One vertebral body only may be affected, and in the case of a dorsal vertebra the rib on both sides may be similarly changed, and this may be associated with an increase in the paravertebral tissues on both sides for some distance above and below the affected vertebræ. In the case of the sacrum the impression is given in some cases that the disease spreads across the joint into the ilium on both sides. The compression of the plastic bodies may give rise to symptoms of pressure on the nerve roots and cord. Several instances of this have been seen in the author's series. One case with compression of the fifth dorsal body and changes in the rib on either side had spastic paraplegia. He was 54 years of age and had had Paget's disease of the tibia for 24 years.

Morlock describes a case of osteitis deformans of the spine in which the deformity of the bone led to a compression myelitis. The patient, a man of 56 years, had had to drag the right leg for 6 years, and after this time his left leg gave way. There was complete anæsthesia below the level of the tenth dorsal and sphincter disturbance.

If lipping of the affected vertebral bodies had occurred prior to the development of Paget changes these osteophytes take on the same characters as the bone of the vertebral body. In the osteolithic type the osteophytes have an increased density and the ossified ligaments take on a massive appearance. The bony fusions, due to old inflammatory lesions, undergo the same sequence of changes.

The natural curvature of the spinal column is exaggerated and ossification of the anterior common ligament, particularly in the dorsal region, is frequent. In spite of the exaggerated dorsal kyphosis, the vertebral bodies do not exhibit a wedge shaped deformity unless this existed before the disease began. The disc spaces appear to preserve their normal depth, though they may appear to show a slightly increased biconvexity. In the osteoporotic type the vertebral bodies show a greater degree of compression and, when most of the column is affected, they are uniformly compressed, in some cases to little more than half of their normal depth. The exaggeration of the lumbo-sacral angle in such cases results in a horizontal disposition of the upper borders of the sacrum and acute flexion of the lower segments.

Vertebral bodies infiltrated with malignant cells from adjacent spinal canal tumour meningioma, sarcoma, or secondary carcinoma from prostate, stomach, œsophagus, etc., may have a density which suggests the osteolithic type of Paget's disease. In some cases pressure on the bone or its vascular supply from an adjacent simple tumour may be associated with localised density of a vertebra. *Velter* reported a case of ivory vertebra associated with lipoma of the spinal canal. Whereas vertebral bodies invaded by angioma have a cleared effect with a bigger pattern of cancellous tissue and a general increase in all dimensions and possibly some compression which suggests the osteoporotic type of Paget's disease (see Differential Diagnosis, p. 614).

The coarseness of the cancellous structure is well illustrated with photographs and radiographs in *Schmorl* and *Junghanns* book.

Juvenile Polyarthritis. The radiographs of the spine of a patient suffering from this condition may show no abnormality in the acute stage beyond general osteoporosis, but after the condition has been present for some months the articular surfaces of the

which may therefore be flattened or concave in shape pressure absorption of the laminæ or of the upper or lower surface of the pedicle with widening of the intervertebral foramen on one or both sides. The eroded vertebra may collapse and curvature be produced. Because of the density of the radiograph of the spine and the penetration used in its taking, unless the observer is on the lookout for it a large paravertebral tumour may escape attention. In the thoracic region attention may be attracted to it by a localised increase in an intercostal space or erosion of the rib surfaces or transverse processes. Such extra spinal thoracic tumours may be relatively symptomless. The author has come across them accidentally when screening a chest prior to a barium meal

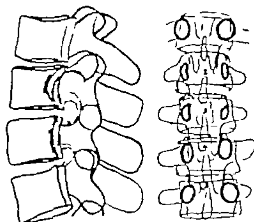


FIG. [illegible] Drawings of radiographs of lumbar spine showing erosion of the posterior surfaces of the vertebral bodies and of the pedicles. Note increase in size of the intervertebral foramina on the lateral radiograph and increase in the interpeduncular spaces on the antero-posterior radiograph.

investigation into gastro-intestinal disturbances. Therefore ordinary radiographs to show the lung fields should be taken in addition to those to show the vertebral structure. The intermuscular extensions usually become obvious to clinical examination from their size and position.

In some cases of neurofibromatosis multiple intervertebral foramina may be enlarged due to pressure from these tumours (see Fig 380)

Though the kypho-scoliosis of neurofibromatosis may be due to vertebral collapse from pressure erosion by tumours, in some cases it is associated with general osteoporosis which may or may not result in collapse of one or more bodies without the agency of localised tumour

Knutsson [8] has recorded 3 cases of Hour-glass Neurinomata.

The radiograph of 1 case shows a small tumour in the interspace between the third and fourth ribs with no widening of the space or bone change, but in another case the interspace between the second and third left rib is widened, and the opposing rib surfaces are eroded, the part remaining showing some sclerosis.

Saupe has published radiographs of a case of *Hodgkin's* disease, showing pressure erosion of the anterior surface of the vertebral bodies.

Elsberg has pointed out that changes in the bones occur in more than one-half of the cases of extra-dural tumours. These changes he tabulates as (1) Enlargement of the vertebral canal (best seen on stereoscopic lateral radiographs) (2) localised defects in one or more vertebræ (3) a scoliosis at or above the location (4) an actual

the interstices of the cancellous mesh have been packed with calcium, obliterating its detail whereas in the osteoporotic type all calcium available has been abstracted leaving a cleared bone with the detail of its bigger pattern of cancellous tissue now clearly visible. These changes in the vertebræ are associated with some general increase in their dimensions—most noticeable in the transverse diameters of the bodies for these acquire a greater amount of plasticity and become more or less compressed by the superincumbent weight. This may be better indicated on lateral radiographs. The disease shows peculiarities in its distribution and extension. One vertebral body only may be affected, and in the case of a dorsal vertebra the rib on both sides may be similarly changed, and this may be associated with an increase in the paravertebral tissues on both sides for some distance above and below the affected vertebræ In the case of the sacrum the impression is given in some cases that the disease spreads across the joint into the ilium on both sides. The compression of the plastic bodies may give rise to symptoms of pressure on the nerve roots and cord. Several instances of this have been seen in the author's series. One case with compression of the fifth dorsal body and changes in the rib on either side had spastic paraplegia. He was 54 years of age and had had Paget's disease of the tibia for 24 years.

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CHAPTER XVIII

THE SPINE (*continued*)

Hyperparathyroidism. The vertebræ in this condition show pressure deformities of the bodies. They become biconcave in shape because of their reduced resistance to the pressure of the intervertebral discs. They show general osteoporosis and destruction of much of the internal cancellous architecture

The superior and inferior borders may show a relative sclerosis as in other forms of osteoporosis as in Fig 411 In some cases localised processes become markedly expanded, their internal cancellous structure completely destroyed or represented by a few coarse septa.

Localised polycystic lesions may be seen in polycystic dysplasia. The expanded lesions of polyostotic fibrous dysplasia are denser and show no septa. But in both of these dysplasias there is no generalised osteoporosis and no pressure deformities only the affected focus shows changes.

Adson[1] describes osteitis fibrosa cystica of the spine in a boy aged 14 years, who developed paralysis of the lower extremities owing to a compression myelitis. His radiographs show destruction of the right half of the tenth dorsal vertebra, with a faint cyst like shadow having a circumscribed linear border between the tenth and eleventh ribs. The affected vertebra was curetted and the patient given X radiation over the area, which resulted in recovery

He describes a further example in a girl aged 18 years The radiographs of this patient show a shell like expansion of the second, third and fourth cervical vertebræ. This area he also curetted with success

Junghagen[2] has published radiographs with a description of the bone changes in cases of Gaucher's splenomegalic anæmia which show changes in the vertebræ indistinguishable from those seen in cases of parathyroid tumour

See also note on *Buxton's* case p. 415



Fig 391 Radiograph of the lumbar spine of a man aged 58, showing the osteolytic type of osteitis deformans. Note the expansion of the third and fourth vertebral bodies. Compare with Fig 414

Osteitis Deformans (Paget's Disease) The earliest radiographic sign of the disease in the spine is either a relative increase (osteolithic type) or decrease (osteoporotic type) in the density of one or more vertebral bodies (see Fig 391), or in some cases, changes in an isolated process

In the osteolithic type the uniform density is such as to give the impression that

Paget's disease of adults. If a fracture occurs in the neighbourhood of what becomes because of inadequate treatment or in some cases in spite of all treatment, the keystone of the arch, these changes will develop the more readily and will progressively increase until consolidation is sufficient to bear this abnormal strain (see p 390 and Figs. 372 and 373)

Radiographs will indicate the degree of curvature and, depending on the condition of the individual, the gravity of the damage, and the time which has elapsed since the causal factor began to act the amount of soft tissue and bone change. Particular stresses and strains of industry acting during the period of debility will bring corresponding changes on the spinal column These changes are frequently referred to under such general headings as osteoarthritis of the spine, or spondylitis, but a more detailed classification is desirable. In addition to the changes referred to above, and those produced by specific diseases, we have those which are related to non-specific infections of the tissues.

ARTHRITIS OF THE ADOLESCENT AND ADULT SPINE

Arthritis of the adult spine may be seen in association with polyarthritis of the



FIG. 382. Antero-posterior radiograph of the lumbar spine of a woman aged 33 showing fusion of the articulations. Gonococcal polyarthritis.

extremities, or as a separate entity involving all the intervertebral articulations or localised in certain areas the chief being the lumbo-sacral, the lower cervical or the dorso-lumbar

It has been recorded as a complication of most of the infectious diseases including

affected vertebral facets lose their sharp definition, and, later definite irregularities of the facets may be seen. Similar changes are shown in the costo-transverse articulations of the thorax.

It is pointed out in the chapters dealing with this affection of the extremities that the limb bones are more slender than normal. This may also apply to the vertebral bodies, which are then definitely longer than their width (see Fig 392) which is the antero-posterior radiograph of the spine of a girl aged 17 who contracted *Still's* disease in infancy Most of the joints show destructive arthritic changes. The hip joints and some of the smaller joints have become ankylosed during *the past 3 years.*

Fig. 392. Antero-posterior radiograph of the spine of a girl aged 17 showing lengthening of the vertebral bodies. Case of juvenile polyarthritis (*Still's* disease).

As in osteoporosis due to other diseases, the upper and lower surfaces of the vertebral bodies may appear to be relatively denser General compression and kyphosis may result.

Occupational Spine. When the normal individual is called upon to perform any function which necessitates the retention of the spine, or any other part, in a relatively fixed position by muscular contraction, he eventually experiences a sense of fatigue. In the young person this sensation is scarcely noticed, it merges into a condition of general tiredness, but with advancing age this fatigue more readily develops and ultimately tends to take *on the form of a cramp* This is usually attributed to a localised accumulation of lactic acid. In healthy individuals the constant activity of the young and the periodical physiological reshuffling of the muscles of the older person, dispels the sensation and restores equilibrium until general tiredness supervenes. So in the case of the fit individual whose spine must be bent over his work, periodical straightening and reshuffling of the muscles preserves normality of the tissues, but it must be appreciated, if the consequences are to be avoided, that no such reshuffling takes place in the fatigued or debilitated worker and, as a result, after a time the tissues subjected to pressure from superincumbent weight suffer The dorsal curvature is increased or if the weight is unevenly distributed over the two sides a lateral curvature is produced. On the concave aspect of the curvature, particularly in the neighbourhood of the keystone of the arch, the soft tissues are compressed and the bony surfaces are brought into closer contact. The latter robbed of the buffer like effect of the soft tissues, are subjected to repeated mild traumata which induce a mild inflammatory reaction. For a time some degree of localised osteoporosis may be seen, but later calcium is attracted to the site the bone becomes sclerosed, the compressed and damaged soft tissues receive deposits of calcium and may ultimately ossify If for any reason the bone is in a semiplastic state it undergoes a corresponding compression—such as is very marked in osteochondritis, rickets, and polyarthritis of young persons, and in osteomalacia and

On the other hand, fusion of the articular facets may occur and all detail of their opposing surfaces be abolished (Type 1 see Figs 303–4)—in other cases it is ossification of the intervertebral ligaments—in particular the anterior common ligament and inter spinous ligaments—which is the striking feature with the gradual development of the so-called bamboo spine (Type 2 see Fig 305) The case may appear for radiographic examination in the first instance with these well marked manifestations

In some of these cases of type 2 the bone surfaces at the site of muscular or liga



FIG. 306. Antero-posterior radiograph f the lumbar spine of a man aged 40 showing ossification of the anterior common ligament, inter-spinous ligaments and ilio-lumbar ligaments, also fusion of the sacro-iliac joints.

mentous insertions may be irregular and woolly Such changes may be seen in the symphysis pubis, tuber ischii etc.

With complete bony ankylosis of the spine, either types 1 or 2, the lumbar spine is flat, the dorsal spine forms a marked regular kyphosis, the curve of which is continued into the cervical area. Such a *patient has no rotation of the spine*, and consequently *has to turn his whole body if he wishes to look behind him* as in the type described by *Bechterew*

In those cases in which, in addition ankylosis of the hips and shoulder joints occurs, the patient will have difficulty in retaining his balance when standing without supports. This type is described as the *Marie-Strumpell* variety

This type of ankylosing arthritis may be associated with evidence of calcifying tuberculous lesions in the lungs. In one patient, a surgeon the first indication of the

Actinomycosis, Gonorrhœa, Diphtheria, Erysipelas Influenza, Malaria, Malta Fever Measles German Measles, Paratyphoid Fever Pneumonia, Puerperal Fever Rheumatic Fever Scarlet Fever Smallpox, Spotted Fever Syphilis, Tuberculosis, Typhoid Fever as well as a concomitant in Rheumatoid Arthritis and non-specific infections.

Certain well-defined types can be distinguished by radiography

Spondylitis Rhizomelica. *Attention is often attracted to the* pathological changes in the spine by an alteration in the appearances of the sacro-iliac joints.

Gilbert-Scott regarded this as the primary lesion—it certainly is the site to which attention is drawn in the early case for changes in the lumbar facets are not easily recognised at this stage, and even when the sacro-iliac changes are obvious the lumbar



Fig. 391. Fusion of all cervical facets. Ankylosing spondylitis.

facet changes may be overlooked. The lumbar spine may show an indefinite degree of general osteoporosis in which one cannot recognise any localised absorption but a suggestion of clearing rendering trabeculæ and more particularly the border outlines of the bodies, in sharper outline, though the outlines of the articular surfaces of the facets may be blurred At this stage there may be no evidence of any ossification of the intervertebral ligaments The disease may resolve without any specific treatment, perhaps with bony ankylosis of the sacro-iliac joints but without any appreciable change elsewhere the condition is one which shows very considerable degrees of severity

A large proportion of these patients show evidence of diverticulitis It is possible that absorption from the intestine is partly responsible Certainly acute signs can be induced by certain laxatives in some cases

Specimens of these lesions in the *Strangeways* Collection kindly shown to me by *Lanford Knaggs* show an appearance which one might expect to be produced if the ligaments had undergone ossification after a preliminary swelling of the fibres by a type of mucinous degeneration they look as if some stringy viscid substance had run down over the surfaces of the vertebræ adhered more to one place than another and had then been ossified. The bones of ancient Egyptians in the Royal College of Surgeons Museum have a similar appearance. The radiographs of post mortem specimens, in which ossification of the ligaments and lipping of the articular margins had occurred show



FIG. 397 Antero-posterior radiograph of the lumbosacral area showing osteoarthritis of the lumbosacral joints.



FIG 398. Radiograph showing marked scoliosis of the lumbar spine with secondary osteoarthritic changes in the articulations which are irregular and sclerosed.

that the new bone is denser and therefore more opaque to the X rays than normal bone

In some cases the lipping occurs on the adjacent borders of two vertebral bodies only—a common finding in the fifth and sixth cervical vertebræ : here the clinical and radiographic signs develop insidiously and eventually are associated with painful movements of the head In cases which have resulted in scoliosis lipping of the bodies may be shown on the concave side of the curvature only and radiographs show that the disc spaces have been reduced on this side and widened on the convex side probably due to displacement of the nucleus pulposus. The borders of the vertebræ which have been brought together may later show secondary osteoarthritic changes a condition

malady was an acute arthritis of an interphalangeal joint of the right hand. In spite of all forms of treatment every joint of the body eventually showed acute arthritis followed by bony ankylosis. His illness lasted about 10 years and for the last 4 years every bone of his body was fused into one. A year before death he became blind. His intellect was preserved to the end.

Type (3) **Localised Arthritis.** The common site for localised arthritis of the spine is the lumbo-sacral area, which is probably due to the fact that this area is subjected to greater strain, forming as it does a junction between the upper mobile spine and the lower fixed sacrum.

At the onset of lumbo-sacral or lumbar arthritis the patient is subjected to attacks of so-called "lumbago" or "sciatica," and radiographs at this stage may show little alteration in the appearance of the vertebræ. The symptoms frequently subside in a phenomenal manner after the efficient treatment of foci of infection such as teeth,



FIG. 206A. Radiograph of the lumbar spine of a man aged 51 years, showing massive ossification of the right side of the common ligament with sclerosis of the adjacent borders of the vertebral bodies. Note the false joint between the projecting lips of the first and second lumbar on the concave side of the curvature.



FIG. 206B. Extensive lipping of vertebral bodies on concave aspects of lumbar spine.

tonsils, sinuses, gall bladder or gastro-intestinal tract, though previously no alleviation had followed the administration of various forms of physical medicine. Because the acute and sometimes distressing symptoms are not associated with radiographic signs the cause may to-day be assigned to a prolapsed intervertebral disc.

Radiographs taken at a later period, 1 or more years, usually show lipping of the margins of the lower lumbar vertebræ and pointing of the articular facets. In some cases this is followed by extensive ossification of the anterior common ligament.

It is possible by radiography to distinguish two types of bone change In the destructive phase there is marked bone destruction and sometimes collapse of the involved vertebræ without any visible new bone formation, but amorphous collections of calcium may be seen in the immediate neighbourhood of the affected joint. In the hypertrophic type destructive erosion of the opposing bony surfaces is accompanied by massive new bone formation, as in Fig 399 Subluxation of the spine may occur at this site.

The commonest site for spinal Charcot s joints is in the lumbar area. There is frequently a history of trauma preceding the abnormal changes, and evidence of tabes dorsalis.

Radiographs illustrating these types of neuropathic joints of the spine with interest



Fig. 400 A.



Fig 400 B.

Neuropathic fracture of fourth lumbar vertebra in tabes.

ing details of the clinical findings are to be found in the papers by *Loewenberg* *Detlev* and *Wehmer* (2 cases), *Garvey* and *Glass* (4 cases) *Pape* (5 cases), *Herndon* (3 cases).

TUBERCULOSIS

The most important lesion of the vertebral column in children is tuberculous caries. The infection may occur in one vertebra only in two or more adjacent vertebræ or in several isolated vertebræ.

In a series of cases recorded by *Whitman*, 50·2 per cent. occurred between the ages of 3 to 5 years, and 82 ˜ per cent. between the ages of 2 to 10 years. The commonest site of the lesion is in the dorso-lumbar area, as in the case of compression fractures, which suggests that trauma may have some influence.

In a series of 1,284 cases reported by *Whitman*, the distribution of the disease was cervical, 100 dorsal, 854 lumbar 317 lumbo-sacral, 13

Radiographic Appearances. In the early stages of the disease even though definite clinical signs may be present, the radiograph may show no change in the bone, *i.e.*,

which is also seen between the opposing surfaces of projecting lips from the vertebral bodies which have failed to fuse (see Fig 890, A).

Localised arthritis as indicated in Fig 872 may follow an attack of typhoid fever

The chief alteration in the radiographic appearance in cases of localised arthritis of the dorso-lumbar area is lipping of the vertebral bodies. In some cases destruction of one or more discs in this area may be inferred from the diminution of the intervertebral space and secondary irregularity and sclerosis of the opposing vertebral surfaces. In the lumbar area slight forward displacement of one or more bodies may be associated with arthritis of the facets. In the cervical area acute arthritis and softening of the interspinal ligaments with resultant dislocation are seen as a complication of tonsillitis and the infectious diseases of childhood, as in Fig 876 (See also Disc Changes, pp. 416–9).

Type (4) Osteoarthritis. Osteoarthritis of the spine is generally localised to two or three vertebræ It appears to follow trauma, and is frequently seen in the lumbo-sacral and dorso-lumbar area. It is also seen in joints, the articular surfaces of which have been injured by previous arthritis or alteration of the alignment owing to curvature (see Figs 897 and 898).

Osteoarthritis also develops in the false or abnormal joints which arise from the destruction of the intervertebral disc, the approximation of the vertebral bodies on the concave aspect of the curvature in scoliosis, the approximation of the spinous processes *to one another in marked lumbar lordosis, or the abnormal lumbo-sacral transverse* articulations (see Figs. 851 853 and 898).

The first indication of the process in the articulations is a diminution of the space between the facets of the articular processes.

It is seen in association with osteoarthritis of the hip joint when the latter is unilateral, the contra lateral sacro-iliac or lumbo-sacral joints may show severe sclerosis, a reaction to the increased prolonged strain.

In false joints or joints which have been damaged by injury or disease, the first indication is sclerosis of the closely approximated bony surfaces. Later osteophytic outgrowths may be indicated by irregular bony growths at the periphery of the joints. Ankylosis between the opposing joint surfaces does not occur *The line of the* joint can usually be clearly seen in radiographs taken in one or other plane. It may be obscured by osteophytic growth at the periphery in one plane. *It is rare for cystic* degeneration of the bone to be demonstrated in osteoarthritis of the spine



Fig 899 Radiograph of the lumbar spine of a man aged 50 years showing massive new bone formation around the second, third and fourth lumbar bodies with marked destruction of the third lumbar vertebra Charcot spine

Radiographs illustrating further examples are to be found in the papers by *Giraudi Sicard, Coste, Belot* and *Gastaud Schmorl* and *Junghanns Knaggs* [1] *Reisner* [1] *Bohmig* and *Prévôt*.

Charcot's Spine. Since the advent of radiography neurotrophic joints of the spine have been frequently reported

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The commonest site for spinal Charcot's joints is in the lumbar area. There is frequently a history of trauma preceding the abnormal changes, and evidence of tabes dorsalis.

Radiographs illustrating these types of neuropathic joints of the spine with interest



Fig 400A.



Fig 400B

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The infection may occur in one vertebra only in two or more adjacent vertebræ or in several isolated vertebræ

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In a series of 1,264 cases reported by *Whitman* the distribution of the disease was cervical, 100; dorsal, 834 lumbar 317 lumbo-sacral, 13

Radiographic Appearances. *In the early stages of the disease* even though definite clinical signs may be present, the radiograph may show no change in the bone *i.e.*,

which is also seen between the opposing surfaces of projecting lips from the vertebral bodies which have failed to fuse (see Fig 396, A).

Localised arthritis as indicated in Fig 372 may follow an attack of typhoid fever

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The first indication of the process in the articulations is a diminution of the space between the facets of the articular processes.

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Fig 399 Radiograph of the lumbar spine of a man aged 30 years showing massive new bone formation around the second third and fourth lumbar bodies with marked destruction of the third lumbar vertebra. Charcot's spine

Charcot's Spine. Since the advent of radiography neurotrophic joints of the spine have been frequently reported

scalloped erosion of the anterior surfaces, and ultimately a wedge-shaped compression deformity of the vertebral bodies involved. The disc spaces may be preserved but the nucleus pulposus may be densely calcified.

Defective ossification of vertebral bodies due to persistence of notochordal tissue may result in radiographic appearances resembling those produced by tuberculosis. *Schmorl* and *Junghanns* published radiographs and photographs of the sectioned spines of (1) a man aged 72 years and (2) a woman aged 26 years. In the former case the notochordal tissue runs through the depth of the vertebral body in its middle third and has resulted in a wedge-shaped deformity of the body. In the second case the notochordal



FIG. 402. Radiograph showing localised tuberculous caries of the left inferior border of the third lumbar vertebral body and adjacent border of the fourth lumbar vertebral body.



FIG. 403. Lateral radiograph of the cervical spine showing tuberculous caries of the second and third cervical vertebræ: a large fully calcified post-pharyngeal abscess and a post-tracheal abscess.

tissue occupied the posterior third of the section of the tenth dorsal vertebral body. The absence of any sign of abscess should warn the observer against the diagnosis of tuberculosis.

In children multiple vertebral bodies are usually involved, whereas in the adult tuberculous caries is most commonly seen in the dorso-lumbar and lumbar areas as a localised erosion of the adjacent surfaces of two vertebræ (see Figs. 399 and 400). The involved vertebræ in such cases do not show any appreciable osteoporosis in the non-involved parts, and for this reason it may be mistaken for a Charcot's joint. The typical spindle-shaped abscess can usually be demonstrated on antero-posterior radiographs when the dorso-lumbar area is involved.

Tuberculous lesions in bone usually leave evidence even when healed. The reconstructed bone is of coarse cancellous structure, but in one case of the author's, a child

there may be a long negative radiographic latent period It may show lateral displacement of the outline of the psoas due to abscess formation (see Fig 401) yet other cases occur in which the clinical signs are indefinite but the lateral radiograph shows areas of bone rarefaction and absorption indicating definite bone destruction. It is possible that such anomalies are due to a different location of the tuberculous focus and the line of progression which the infection takes.



Fig 401 Early caries of second lumbar vertebra. Note deviation of outline of psoas due to abscess.

Appearances in the spine equivalent to those described on pp 71 72 and 206–9 may be seen.

Commonly the pathological changes are first seen in the juxta epiphyseal area near the anterior aspect of the inferior surface of the vertebral bodies, and may at this stage, resemble the appearance of *Schmorl's* nodes, *i.e.* projections of cartilage from the disc into the vertebral bodies (see Fig 384 D). It is rare for the disease to begin in the neural arch or processes ; but this is seen occasionally When the process commences in the bone, destructive changes occur which can be shown on the radiograph, but the ligaments and external surfaces of the bone are not involved therefore the clinical features may be few unless, as sometimes happens, the diseased bone is injured. In the latter case the typical clinical features may develop after a few days, as in those cases where the lesion has previously been near the surface of the bone and involved the ligaments early Within the area of bone erosion an amorphous sequestrum may be seen, as in Fig 384 D This *appearance may be simulated by calcification of the nucleus pulposus. Radiographs* may show some sclerosis of the bone around the diseased rarefied area, but in those patients in whom the resistance to the infection is poor the rarefaction is more extensive and there is little evidence of sclerosis.

When the lesion has involved a large proportion of the vertebral body the radiograph will show a " stippled " appearance of the bone probably due to small necrotic bone fragments and irregularity due to erosion of the outline of the body which is gradually crushed between the vertebræ above and below There is usually little or no evidence of new bone formation at this stage unless there has been secondary septic infection of the part.

In some cases, more particularly in the mid-dorsal area, the infection spreads, *via* the paravertebral tissues to several vertebral bodies above and below the original focus. Lateral radiographs in these cases show generalised osteoporosis of the vertebræ with

between the radio-transparent lung at its postero-medial border and the radio-opaque vertebral structures. Any increase in the bulk of the latter will cause the former to be pushed laterally. The outline of the abscess cannot therefore be seen below the lowest margin of the lung unless calcium has been deposited within it (see Figs. 408 II and III).

In the mid lumbar area no indication of the abscess may be seen until its contents have undergone a certain amount of calcification (see Figs 406 and 407). It may show



FIG. 406. Lateral radiograph of the lumbar spine showing tuberculous destruction of the second lumbar vertebra and erosion of the adjacent surfaces of the bodies of the first and third lumbar.



FIG 407. Antero-posterior radiograph of the lumbo-sacral area showing tuberculous caries of the lumbo-sacral joint with a large abscess containing calcified débris overlying the sacrum.

by a lateral displacement of the outline of the psoas as in Fig 401. Commonly in this area an abscess develops on each side. These, when calcified, appear on the radiograph overlying the shadow of the kidneys, which they may somewhat resemble in shape and size. The outline of these lumbar abscesses when large often follows the line of the psoas muscle into the pelvis.

In the lumbo-sacral area also no indication of abscess formation can be seen on the radiograph until calcification has taken place. When this has occurred, the radiograph shows that the outline of the abscess closely follows the outline of the sacrum except for the roundness of its lower border. Shadows of calcium deposits may be seen in the base of these lumbo-sacral abscesses before the general outline of the abscess has become visible (see Fig 407).

Associated with spinal caries and the fixation of the patient in the recumbent position on a frame, marked osteoporosis of the bones of the pelvis may be present. In one case in the series the body of the ilium on both sides was decalcified except for a very

of 16 months who showed destructive lesions in the second lumbar body and femoral neck the lesions healed so completely that the remnant of the affected vertebral body 6 years after had the appearance of a congenital hemivertebra.

Abscesses. Abscesses developing in association with tuberculous caries of the spine have a characteristic appearance in certain areas

In the cervical region the recently formed abscess is indicated on the lateral radiograph of the neck by the displacement forwards of the shadows of the pharynx, larynx or trachea. When the abscess has been present for some time, calcification of the contents occurs, and its actual outline can then be demonstrated as in Fig 403



FIG. 404 Antero posterior radiograph showing tuberculous caries of the tenth dorsal vertebra and a large paravertebral abscess. The shadow of the latter simulates the heart shadow



FIG. 403 Paravertebral abscess with caries of dorsal spine. Not erosion of one rib and deposition of calcium granules in abscess

In the dorsal area the abscess can be detected as a spindle-shaped shadow which includes the shadow of the affected vertebra. In some cases the abscess shadow extends the whole length of the dorsal spine In the dorso-lumbar area the shadow of the abscess may resemble that of the heart shadow and in some cases has actually been mistaken by inexperienced observers for the heart shadow (see Fig 404).

The lateral outlines of the fusiform shadow represent the line of demarcation

in a direct sagittal line for two or more inches For the whole of this distance it is separate from the vertebral body by the pleura, fascia and some areolar tissue. On a plane with the anterior surface of the vertebral body it is displaced laterally by the descending aorta and more anteriorly by the heart. On the right side the medial border of the lung extends partly over the anterior surface of the vertebral body and is displaced

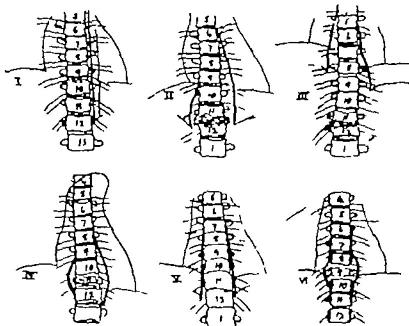


FIG 410. Reduced tracings from radiographs showing the postero-medial border of the lungs in various conditions: I, Left linear paraspinal shadow running parallel with lateral borders of the dorsal vertebræ. Still more lateral is the *outline of the* outer border of the descending aorta. Note that the paraspinal line ceases at the level of the inferior border of the lung II Postero-medial border of the lung *pushed laterally* by a paravertebral abscess associated with caries of the eleventh and twelfth dorsal vertebræ. The outline of the abscess is not indicated below the inferior border of the lung III, Postero-medial border of the lung pushed laterally by a paravertebral abscess associated with caries of the eleventh and twelfth dorsal vertebræ. Note *in this* case the diaphragm is elevated and the visible outline of the abscess ceases high above its origin. IV Postero-medial border of the lung pushed laterally by a hæmatoma associated with a crush fracture of the eleventh dorsal body V Postero-medial border of the lung shown as a bilateral paraspinal line on both sides in a case of osteochondritis of the dorsal spine. VI Postero-medial border of the lung pushed laterally by an abscess associated with collapse of the ninth vertebral body Early case of vertebra plana. A month after the abscess was no longer visible.

laterally by the œsophagus and the heart. Antero-posterior radiographs of this area will therefore show the postero-medial boundary of the left lung as a straight line lateral to the outline of the vertebra because on the lung side of the boundary the tissue is relatively radio-transparent, whereas on the vertebral side the tissue is much more radio opaque (see Figs 408 and 409)

The descending aorta, being more opaque than the *lung* will also be seen as a lineal shadow lateral to the postero-medial border of the lung where it is superimposed over the postero-medial aspect of the lung On the right side because of the shelving margin of the postero-medial aspect of the right lung there is usually no sharp line of demarcation between it and the denser medial structures, consequently the border cannot be seen under these circumstances It *is for the* same reason that the more anterior of the medial

narrow rim of bone in the crest. The displaced calcium may be seen in the shape of stones in the urinary tract.

Healing of the tuberculous caries is suggested by consolidation of the affected vertebræ, sometimes with ankylosis to the adjacent vertebræ, and rounded moulding of the eroded borders, and an increase in the density of the bony trabeculæ which often appear to be much coarser than normal. Shrinking in the size and irregularity of the outline of the calcified abscess are also observed.

Deformities. In the cervical area caries frequently leads to obliteration of the normal forward curvature and the formation of a kyphos. In the dorsal area a kyphos is the usual result. If the lower dorsal vertebræ are involved, the kyphotic deformity is associated with a pronounced lumbar lordosis

Lumbo-sacral tuberculous caries when treated on a frame usually results in obliteration of the lumbo-sacral angle and flattening out of the normal lumbar curve. Neglected lumbo-sacral tuberculosis may result in forward or backward dislocation of the sacrum (see Fig 366)

Differential Diagnosis. *The Paravertebral Shadow (see below).*

The appearance of a knuckle kyphos may be due to —

(*a*) Congenital abnormalities of the neural arch.
(*b*) Osseous dystrophies and dysplasias
(*c*) Spondylolisthesis
(*d*) Injury
(*e*) Inflammatory lesions other than tuberculosis, *e g.*, paratyphoid and allied fevers, sepsis, actinomycosis, etc.
(*f*) Neoplasms
(*g*) Aneurysms

THE RADIOGRAPHIC POSTERO-MEDIAL BORDER OF THE LUNG OR THE LINEAR THORACIC PARASPINAL SHADOW

Under the latter title an editorial in Radiology August, 1942, p 229 draws attention to "a slender line of demarcation which is often seen in antero-posterior or sagittal roentgenograms of the bony thorax and upper abdomen. This line lies on the left side of the lower two-thirds of the thoracic spine and sometimes continues as far down as the plane of the first two lumbar segments. The shadow is frequently an enigma to radiologists and other clinicians viewing such roentgenograms. It is not visible on all films or projections of this portion of the body but is observed with such frequency that it must be the result of variation in the course and position of a normal structure situated therein." Then follows a discussion in which it is inferred that it is not bony not due to unilateral spinal ligaments, descending aorta or inferior vena cava, "but it might be an enlarged and elongated hemiazygos vein." "This editorial is written with the suggestion that this finding be referred to as the left thoracic paraspinal shadow and that its frequency be noted by various radiological observers In this manner its true incidence may be ascertained and its apparent nature confirmed.

The radiographic line of demarcation is of great importance in the diagnosis of lesions involving the lower dorsal and upper lumbar spine It is frequently seen on the antero-posterior radiographs of the dorso-lumbar area on the left side, but it is seen, though less frequently on the right side as well. It extends upwards sometimes to the level of the fourth dorsal vertebra, but downwards only as far as the lower border of the lung for *it marks the postero-medial border of the lung* As will be seen from the line drawing of a cross-section of the body at the ninth dorsal level (see Fig 400), the postero-medial border of the left lung which has been more thickly outlined for emphasis, lies

calcium has been deposited within it (see Fig 401) The line of the psoas may appear to be continuous with the line of the postero-medial border of the lung

Because of this common appearance of the dorsal tuberculous paravertebral abscess there is a tendency to diagnose all fusiform deviations of the postero-medial borders of the lung as tuberculous in origin; but appreciation of the anatomical features I have described, which give rise to these shadows, should induce further discrimination Thus neoplasm, both primary and secondary may cause collapse and an increase in the transverse diameter of the diseased vertebral body—this will cause a lateral deviation of the postero-medial border of the lung which will be increased if there is proliferation of neoplastic cells or if associated with hæmorrhage to such an extent that it may resemble a paravertebral abscess. It should be remembered, however as a feature in differential diagnosis, that neoplasm appears to spare the disc even though all the vertebral body is destroyed.

The paravertebral tissues in the region of the mid-dorsal spine is the site for development of heterotopic bone marrow masses These rounded extra pleural tumour like masses lie on the sides of the vertebral bodies and the posterior extremities of the ribs filling the costo-vertebral angle They do not erode the vertebræ or ribs or lead to destruction of the discs. Their radiographic appearance may be mistaken for those of a tuberculous abscess, primary growth or the secondary deposits of malignant tumour (such as may be seen in *Ewing's* sarcoma) The pelvis and skull may show circumscribed areas of osteoporosis but these are not so well defined as in myelomatosis

The majority of the patients in which these bone marrow masses have been found have been females with severe anemia usually associated with acholuric jaundice It is regarded as a compensatory phenomena. *Ask Upmark* has published illustrations and details of a case in which he believes the primary factor to be emboli or metastatic displacement of bone marrow through the intercostal veins, facilitated by the condition of the marrow the secondary factors will be the compensating enlargement of the new dominion of bone marrow induced by the drain of hæmolysis.

Fusiform paravertebral expansions have been seen at the site of pneumococcal, typhoid and paratyphoid abscesses. In these the destructive changes are more frequently seen in the disc which appears to collapse and within a few weeks the postero-medial border of the lung is straightened out again. The vertebral bodies ultimately fuse

In the acute phase of certain cases of Vertebra plana the involved body is surrounded by fusiform expansion which within a few weeks gradually disappears, leaving the discs apparently intact but the elements of the vertebral body compressed to a quarter or third of its normal depth.

In Paget's Disease which is localised to one or more dorsal vertebral bodies the postero-medial border of the lung is deviated laterally by the expansion of the vertebral bodies.

In osteochondritis of the spine in infants and adolescents some degree of thickening of the tissues adjacent to the vertebral bodies occurs, and the medial border of both lungs may become apparent just lateral to the border of the vertebral bodies, but in this there is no localised fusiform expansion.

In one case rupture of the posterior wall of the aorta was associated with hæmorrhage into the areolar tissue surrounding the vertebral bodies and an appearance simulating a paravertebral abscess was produced.

Localised thickening of the pleura or localised empyema at this site also displaces the postero-medial border of the lung laterally

Any inflammatory or neoplastic proliferation within the vertebral body or the areolar tissue surrounding it may produce changes such as have been described, and

borders of the lung, also the anterior and posterior borders of the inferior extremities of the lung, are not shown.

A glance at the line drawing Fig 409 will show at once why this line is of great diagnostic significance, for it shows the close relationship of the medial border of the lung to the lateral surface of the vertebral body The postero-medial border of the lung will be displaced laterally by any expanse in the tissue medial to it whether it be pleural, intra pleural, paravertebral or vertebral. If the vertebral body is crushed its transverse diameter will be increased and the medial border of the lung will be displaced to that extent laterally If the fracture is associated with a paravertebral

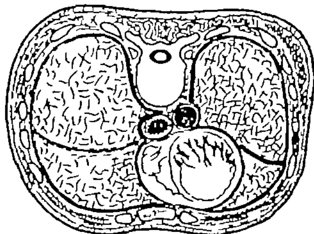


FIG. 409 Transverse section of body at ninth dorsal level The thickened lines are of the postero-medial border of the lung

hæmatoma this will show as an added expansion and further lateral displacement of the medial border of the lung

The antero-posterior radiograph shows this as a fusiform expansion of the medial opacity for the postero-medial border of the right lung will be similarly displaced. In a case which came to court the presence of a crush fracture of the vertbral body was disputed until the presence of a paravertebral hæmatoma was demonstrated to the judge on the radiograph taken immediately after the accident, and its absence from radiographs taken a fortnight later But the commonest demonstration of lateral displacement of the postero-medial border of the lung is due to the paravertebral tuberculous abscess It is important because it may be detected before any change in the bone has become apparent. The abscess may extend the whole length of the dorsal spine, usually fusiform in shape, sometimes of the width of the heart shadow and indeed has been missed because it was mistaken for the latter It may show progressive expansion from the time it was first detected. Because from the lowest level of the lung there is below no contrast in the densities of the adjacent tissues the outline of the abscess cannot be traced in the abdomen, *i.e.*, we are dependent upon the lateral displacement of the postero-medial border of the radio-transparent lung for visualisation of the abscess. Consequently though the abscess may have arisen from caries of one of the lumbar vertebræ, if no bone changes are yet recognisable its origin may not be apparent. Incidentally it may be stated that in the abdomen a lateral deviation of the line of the psoas muscle may help us to detect the site of an acute abscess or a chronic abscess before

bones Increased density of an isolated body may be associated with an intraspinal lesion such as a meningioma or lipoma.

(*b*) **Carcinoma.** There is often a history of a primary focus in the breast prostate thyroid, kidney etc. The latent negative radiographic period may extend into months though the pain may be described as intense throughout the period

The radiographs may show either absorption of the bone calcium and an obliteration of the structural detail of the bone, suggesting that it is being gradually dissolved with no evidence of any new bone formation but often evidence of collapse (as in Fig 410) or an increased density of the bone and obliteration of its internal cancellous structure or the appearance shown in Fig 411 The affected body when dense does not show an obvious change in size: it is not compressed and expanded as in Paget's disease.

Osteomata may be multiple The history shows that the tumour has been present for a long time and that its growth is slow There is often no pain, unless the osteoma

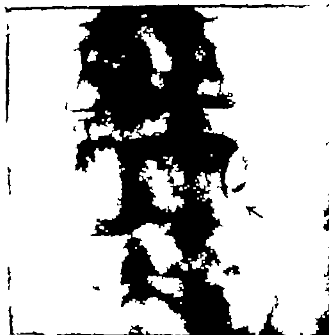


FIG. 412. Osteoclastoma of pedicle of the fourth lumbar vertebra.

interferes with other structures It may compress the cord and cause symptoms of varying severity The radiographs show that the structure of the tumour resembles that of normal bone

Osteoclastoma. The affected body or process shows expansion of its outline sometimes with irregularly disposed coarse trabeculæ (see Fig 412)

Aneurysm. Aneurysm of the abdominal aorta may rupture into the sheath of the psoas muscle and produce an abdominal tumour which on palpation may suggest a psoas abscess

A lateral radiograph of the spine may show the characteristic erosion of the vertebral bodies (see Fig 880) The scalloped outline may be duplicated because of unequal erosion on both sides (see p 423).

it may be necessary to seek elsewhere for a clue as to the identity of the organisms and cells producing the displacement of the lung

Congenital abnormalities are often unaccompanied by pain, and the antero-posterior and later radiographs will show the nature of the abnormality

Spondylolisthesis generally shows a characteristic deformity of the lumbo-sacral area, often unaccompanied by pain. Tuberculous destruction sufficient to produce this deformity would be accompanied by pain, muscular rigidity of the part and probably abscess formation. In spondylolisthesis the radiographs will show the dislocation of the vertebral bodies which are regular in outline and density

Inflammatory Lesions other than tuberculous are usually accompanied by more new bone formation, destruction of the disc and fusion of adjacent surfaces, and the radiographs will show this. Syphilitic and actinomycotic lesions of the spine may give radiographic appearances indistinguishable from tuberculosis.

Rolleston and *Frankau* have recorded the details of a case of acute leukæmia in which changes in the spine occurred simulating tuberculous caries

Hodgkin's Disease in some cases is associated with deposits of lymphadenomatous



FIG. 410. Osteoporosis and compression of five vertebral bodies. Lymphadenoma (*Hodgkin's disease*).

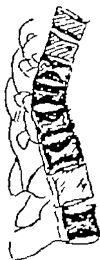


FIG. 411. Irregular sclerosis and osteoporosis of vertebral metastatic carcinoma.

tissue in the bones of the spine The radiographs in such cases show areas of rarefaction, collapse or pressure deformities of the vertebral bodies resembling the appearance of secondary metastases of carcinoma rather than tuberculosis (see Fig 410).

Neoplasms. (*a*) Sarcoma usually shows a greater tumour deformity which has developed rapidly The radiographic appearance varies with the type of sarcoma In some cases the bone is eroded, but the erosion is not confined to the vertebral body as is commonly the case in tuberculosis. The soft tissue tumour mass may be enormous but the bone destruction small. The presence of isolated erosion unaccompanied by abscess formation of any part other than the body usually indicates the more serious lesion The osteoplastic type of sarcoma shows an increase in the density of the involved

the cervical vertebræ fused together and all the bones of the upper extremity showed a marked increase in density

In some cases of syphilis, radiographs of the spine show massive new bone formation around the articulations or if scoliosis exists, around the opposing surfaces of the vertebral bodies, particularly on the concave aspect of the curvature. This new bone presents a greater bulk and density but a less clearly defined margin than is seen in osteoarthritis of the spine Some displacement of the vertebræ may occur at the apex of the curvature (see Fig 413)

Syphilis is also responsible for neurotrophic and aneurysmal lesions of the spine these have been dealt with in previous chapters.

OSTEOMYELITIS

Prior to the use of penicillin and the sulpha-group osteomyelitis of the spine was invariably fatal With their use an increasing proportion of cases recover and in these we have been able to see the sequence of radiographic appearances As in other sites, the clinical signs of osteomyelitis of the spine in the early acute phase are prominent, but there is a latent negative radiographic period of at least two weeks before radiographs will register any appreciable change The earliest radiographic sign is a relative osteoporosis of the affected vertebra. In some cases the site of the primary focus may be indicated by its greater localised decalcification. Within the next 2–4 weeks the changes become definite The younger the patient the shorter the latent negative radiographic period and the more complete the destruction appears to be In infancy the affected vertebræ may appear to be wholly decalcified but the disc spaces may be preserved as in the case described by *Findlay* There is no doubt about the date of onset in this case. The infant aged 1 month had an unsuccessful lumbar puncture made because of meningeal inflammatory signs Four days later the needle track was found to be septic, and in 3 more days a swelling could be seen over the second and third lumbar vertebræ which showed some decalcification. A month later the bodies of the second and third lumbar vertebræ were almost completely decalcified The patient also developed periostitis of the left femur subluxation of the left hip joint and osteitis of one of the phalanges On sulphathiazole and later penicillin the patient recovered and ossification of the remnants of the lumbar bodies was demonstrated radiographically—the disc spaces were preserved. In other cases the infective process appears to be confined to the disc around which in the dorsal area a paravertebral abscess may be seen. In the young adult after a latent period of 2–4 weeks radiographs may show a progressive general compression of the affected vertebral body until it is little more than a millimeter in thickness but as regeneration occurs, an involucrum of new bone gradually builds up the body and when complete there is little indication of its former disease For instance, in one patient investigated by the author a man aged 24 years complained of severe pain in the back and showed the clinical signs of acute osteomyelitis of a localised area the first radiographs failed to reveal any abnormality Radiographs 2 weeks later showed a slight degree of osteoporosis of the second lumbar vertebral body which might easily have been missed if the clinical features had not been appreciated Two weeks later marked decalcification of the vertebra was seen rather resembling in appearance secondary carcinoma. Serial radiographs during the next three months showed a progressive regular compression—eventually the affected body was but ¼ inch in thickness, its anterior body projecting forward beyond the line of the adjacent bodies. None of the vertebral processes were affected—the pedicles had the impression of being separated because the flattened body appeared to be below the level of the pedicles. Three months after evidence of reorganisation of the body was apparent.

SYPHILIS

Syphilitic lesions of the spine are relatively infrequent. They may appear as localised gummata or multiple arthritis of the vertebral articulations with involvement of the discs and adjacent surfaces of the vertebral bodies.

Gummata of individual vertebræ may be seen. The involved vertebra may present a radiographic appearance which is indistinguishable from localised caries with abscess formation, as in the case described and illustrated by *Sinding-Larsen*.[1] The radiographs of this patient, a man aged 31 years, show destructive erosion of the vertebral bodies and a spindle-shaped abscess surrounding it. Ankylosis of the affected bodies and



Fig. 413. Radiograph of lumbar spine showing sclerosing syphilitic spondylitis with scoliosis and some displacement at the apex of the abnormal curvature

complete absorption of the abscess occurred in the course of 12 months, during which time the patient received medicinal doses of mercury and potassium iodide.

The involved vertebra may appear larger than its neighbours, because of the formation of much dense new bone around the periphery. A central area of rarefaction can be demonstrated in some cases. This was seen in a youth 17 years of age.

Marked destruction of the fourth and fifth cervical vertebral bodies by a gumma was seen in a woman of 56. There was sclerosis of the surrounding bone, and consolidation of the diseased bone followed anti-syphilitic medication.

In another case, a soldier of 35, most of the cervical vertebræ showed osteoporosis with destruction of the discs and erosion of the vertebræ. This patient sustained a spontaneous fracture of the middle third of the humerus. A radiograph of the upper extremity was taken which showed not only fracture and osteoporosis of the humerus, but decalcification of the inner half of the clavicle. Following anti-syphilitic medication

he appearances of lymphadenomatous deposits in bone are indistinguishable from certain metastases of carcinoma, unless radiation treatment has been given.

Bony lesions due to lymphadenoma usually show a very much better and quicker response to X radiation than metastatic carcinoma. The clinical features of the case under review will usually decide the diagnosis. Erosion of the bodies of the dorsal vertebræ as in aneurysm may be seen as the result of pressure from enlarged lymphadenomatous glands.

Parkes Weber points out that periosteal lymphogranulomatosis seems to commence symmetrically in front or at the sides of the bodies of the vertebræ about the level of the diaphragm, and then tends to spread round so as to involve the spinal canal and the epidural fat It may account for cauda equina symptoms and paraplegia in *Hodgkin's* disease. It may become sarcomatous, as may the nodules of neurofibromatosis

Lockwood, Johnson and *Marr* in a paper describing the bony lesions of *Hodgkin's* disease in a boy of 15 years, publish radiographs showing normal vertebræ in 1927 but central rarefaction of the vertebral bodies in 1928 and almost complete collapse of the first, third and fourth lumbar bodies in 1929 the discs remaining intact.

The radiographs illustrating lymphadenoma of bone in *Grudzinski's* paper show marked rarefaction of the lumbar spine with irregular amorphous calcium in some of the bones.

Blount discussed lymphadenoma as an orthopædic problem, and published radiographs of a case showing collapse of two mid-dorsal vertebral bodies but no narrowing of the discs. The patient, a girl of 17 years, had been treated as a case of tuberculous disease for 18 weeks.

Hulten [1] described and illustrated the bone changes which were found in the vertebræ of a man of 40 who was suffering from *Hodgkin's* disease The radiographs of his case show that some of the vertebral bodies are decalcified and crushed to a flat disc while others are sclerosed thus, for example, the sixth thoracic is normal, the seventh shows diffuse osteoporosis the fifth is decalcified and partially compressed, the ninth appears to be flaky in the posterior third, the tenth densely sclerosed throughout, the eleventh similar to the tenth, but to a lesser degree, the twelfth normal, the first lumbar shows irregular osteoporosis, the second pronounced diffuse condensation, the third flaky condensation at the antero-inferior border and the fourth a diffuse increase in density rather less than the second. All the disc outlines appear to be preserved

Arnell, Friedrich,[1] *Berron, Ginsburg* [1] *Saupe* and *Kremser* [1] have published radiographs and details of cases showing bone changes in *Hodgkin's* disease.

ANGIOMA OF THE VERTEBRÆ

By the pathologist who sections the vertebral column of every subject which he examines, angioma is the commonest lesion found.

Thus, *Töpfer* found these tumours in 257 out of 2 154 spines which he examined by sagittal section (11 93 per cent.) and *Schmorl* found 115 in 1 142 subjects.

They are found in increasing frequency with age. In 4·5 per cent. of persons under 20 years, in 18 per cent. of those between 20 and 50 years, and in 36 per cent. of those over 50 years.

Virchow is credited with describing the first case in 1862 These findings have little relationship to the radiographic findings in the living subject. Angioma of the vertebræ radiographically is relatively rare. Its appearances are characteristic.

The involved vertebra has a body which has a slightly greater transverse diameter and slightly less depth than the normal vertebræ above or below If the spinous and transverse processes are involved these will also show greater dimensions than the

In the adult a more localised process is seen and with it sometimes a change in the alignment. The latter depends on the degree of mobility permitted during the active stage (in infants and adolescents there is usually little resultant deformity) The intervertebral ligaments over several vertebræ become ossified and produce rigidity of that sector of the spine. Greater deformity results if mobility is permitted before consolidation is complete. When the condition enforces absolute rest of the spine little alteration of alignment occurs. The curvatures may show some flattening out and the spine becomes permanently fixed by ossification of its ligaments.

Those cases in which a chronic inflammatory process persists will show a varying amount of bone destruction and, if healing is taking place, sclerosis of the surrounding bone and sometimes massive deposits of new bone. Sequestra may be shown.

Whitman gives the following tables showing the situation of the lesion in acute osteomyelitis of the spine in 61 collected cases —

Cervical region	12
Thoracic	15
Lumbar	24
Sacral	10

He states that, in 30 of 53 cases reported by *Grisel*, the patients died of general infection, pleuropneumonia or meningitis before the diagnosis had been made and before an abscess developed.

	Recovered.	Died
Suboccipital	1	4
Cervical	2	2
Dorsal	7	3
Lumbar	13	15
Sacral	0	6
	—	—
	23	30

Actinomycosis. The affected vertebræ may show multiple round fairly well-defined areas of decalcification as illustrated in Fig 151 yet without collapse of the body Abscess formation may not be a prominent feature In the chronic type a sclerosis and thickening of the surrounding bone develops

Typhoid Spine Radiographic examination of the spine following typhoid or para typhoid fever may show ossification of the intervertebral ligaments, destruction of the discs, localised osteitis, ankylosis of the articular facets, chronic abscess or fusion of two or more vertebræ.

As in all acute bone infections the first radiographic sign may be osteoporosis, paravertebral abscess, or diminution of the disc space The appearance indicative of the lesions mentioned may not be seen until the acute symptoms have passed.

Rummell, in describing the radiographic appearance of the spine of a girl aged 17 years who had had typhoid fever draws attention to localised ossification of the anterior common ligament, as in Fig 372 Radiographs illustrating the various bone and joint lesions met with in typhoid fever are to be found in the papers by *Bakir Keith* and *Keith Krause Lyon*,[1] and *Schmorl* [2]

In a previous chapter it was mentioned that spondylitis in its various forms may occur as a complication in most of the infectious diseases.

Lymphadenoma (Hodgkin's Disease). In a proportion of cases of *Hodgkin's* disease deposits of lymphadenomatous tissue develop within the vertebral bodies and result in localised sclerosis, or rarefaction, erosion, or collapse, as in Fig 410 Radiographically

Bailey and *Bucy* have recorded cavernous hæmangiomata of the third, fifth and sixth dorsal vertebræ in a patient of 62, who for 10 months had signs of compression of the spinal cord

Töpfer reviews the literature respecting these tumours, and points out that some cases have been operated upon successfully and that in others symptoms have been alleviated or dispersed by X radiation to the tumour

Fwing refers to a case in which such a tumour in the dorsal vertebræ protruded into the canal and compressed the cord. In this case the involved vertebra collapsed.

The frequency with which the larger hæmangiomata of the vertebræ produce symptoms, in patients showing a wide age distribution is indicated by the brief details of the following cases :—

(1) *Dietz's* case a woman of 42, died from compression myelitis Angiomata of the liver were also found post-mortem

(2) *Gerhardt's* case a boy of 17 complained of pains in the back and subsequently developed paraplegia. He died of erysipelas 6 years later At post-mortem examination hæmangiomata of the fifth and sixth thoracic vertebræ were found pressing on the spinal cord.

(3) *Globus* and *Doshay's* case a girl of 13 complained of weakness of the back, and later developed sphincter disturbances and paraplegia Hæmangioma of the twelfth thoracic vertebra was found. The patient died of hæmorrhage

(4) *Gold's* case a man of 23, complained of weakness of the legs and later developed paraplegia Hæmangiomata of the first second, seventh and eighth thoracic vertebræ with cord compression were found

(5) *Guillian Decourt* and *Bertrand's* case a youth of 16 complained of pain in the back and later developed paraplegia At post-mortem examination hæmangiomata of the seventh, eighth and ninth thoracic vertebræ were found.

(6) *Muthmann's* case a woman of 61 had complained of sciatica for 16 years. She developed weakness of the legs and a kyphosis which was tender on pressure At post-mortem an angioma of the sixth thoracic vertebra was found pressing on the cord.

(7) *Perman's* case a woman of 27 complained of weakness of the legs and later developed a pa tic paraplegia due to hæmangioma of the fifth thoracic vertebra which compressed the cord.

(8) *Ramage* and *Vallrey's* case a man of 51 complained of weakness of the legs and later developed ataxia and spasticity of the legs. The radiograph showed a hæmangioma of the eighth dorsal. This was treated with X radiation, and improvement is reported.

(9) *Ireland's* case a woman aged 25 years, had pain and discomfort in the lumbar region but with intervals of freedom. Later pain in the epigastrium occurred.

Further illustrations are to be found in the papers by *Maerycostas* and *Reiner* in which the recorded cases are reviewed

Intra-spinal Tumours. Intra spinal tumours such as Meningioma, Glioma, Neuroma, Angioma, Lipoma may be detected radiographically by —

(1) Reaction in the adjacent bone, sclerosis with increased density sometimes involving the whole vertebral body osteoporosis or erosion.

(2) Increased width between the inner margins of the pedicles—these in the normal on the antero-posterior projection are almost round, but as the result of the pressure absorption their medial border is absorbed and may become slightly concave the pedicle appearing to be flattened or crescentic in section (see Fig 380).

(3) Deformity or obstruction of the canal as shown by injected lipiodol. Examples have been published by *Elsberg* and *Dyke*

Extradural cysts may be associated with **Kyphosis Dorsalis Juvenilis** and produce progressive paraplegia. Etiology is unknown. Surgical removal cures and arrests the kyphosis.

A pseudo-tumour of the spinal canal was recorded by *W E Dandy*—this was found to be a shell of bone surrounding the posterior half of the spinal cord—in the

normal. The angiomatous bone is less dense than the normal, the finer trabeculæ and the interstitial calcium are absorbed, and a very coarse but regular trabeculation is seen, which factors give the vertebra a cleared effect in contrast to the general ground-glass appearance of the normal. These coarse trabeculations, as shown in Fig 414 follow the direction of the normal bone striations, so that in the antero-posterior radiograph they appear to be vertical in the bodies, horizontal in the transverse processes, and end-on in the spinous processes The tumour appears to pervade the whole structure



Fig 414 Antero-posterior radiograph of the lower lumbar spine showing the typical appearance of angioma of the third lumbar vertebra. Note that the spinous and transverse processes are involved as well as the body

of the involved bone completely changing its internal cancellous architecture, leading to some expanse of the bone but not causing any appreciable alteration or irregularity in its surface contour

The lesion which most closely simulates angioma of the vertebræ is the osteoporotic type of **Paget's Disease** (see Fig 301)

In some cases **Localised Cavernous Angiomata** lead to destruction of more or less of the whole body or process resulting in collapse later

Such a vertebra may collapse with relatively slight trauma or may bulge into the spinal canal and compress the cord Lipiodol injections preceding radiography will help to decide if and where compression exists.

One or more vertebræ may show these typical appearances The discs are not involved In 2 cases seen by the author the patients complained of pain and discomfort in the back and abdomen The patients were submitted to X ray investigation with a presumptive diagnosis of a gastro-intestinal lesion.

rest of the vertebræ These areas gradually fuse until the whole texture of the vertebræ is altered The vertebræ may now appear so dense as to be called ivory vertebræ or so transparent that one must infer complete decalcification, as in Fig 415

Between these widely different appearances many variations are to be seen These appearances may be discovered long before the primary neoplasm has been suspected or detected.

The involved vertebræ may disintegrate so completely that the clinician may fail to detect any abnormality on the antero-posterior radiograph. A lateral radiograph



Fig. 415. Lateral radiograph showing complete decalcification of the body and pedicles of the third lumbar vertebra Secondary carcinoma.

will usually show the lesion very distinctly One or more vertebral bodies may collapse Distinct from tuberculous caries, the collapse of the carcinomatous body tends to be uniform rather than wedge-shaped and the discs appear to be spared.

Multiple rounded areas of osteoporosis of the vertebral bodies and ribs are suggestive of myelomatosis and examination of the urine for *Bence-Jones* albumose is indicated

When the lesions are confined to one vertebra, great benefit may be afforded the patient by X radiation of the area, as such radiation often results in recalcification of involved bone; collapse and displacement with resultant deformity and pain and months of invalidism may be so prevented.

Jacobi has illustrated the radiographic appearance of myelomatosis in a child 8 years of age. The radiographs show biconcave deformity of the lumbar vertebræ and wedge-shape deformity of the dorsal vertebræ. The margins of the vertebræ are well defined but little cancellous structure can be deteteed. The disc spaces are wider and biconvex. The child died after 9 months illness.

lumbar region this was broken up at the levels of the discs but in the thoracic region was entire

Osteoclastoma. *The first radiographic sign of this tumour is a localised area* cancellous destruction, as the tumour cells infiltrate the bone the finer trabeculæ wiped out, leaving only a few coarse irregular trabeculæ. When the whole body process is involved it is expanded, more perhaps in one part than another but t periphery is usually outlined in bone The disc spaces above and below appear unaffecte *It is slow growing and symptoms may be present for two or more years before the natu* of the lesion is determined. In other cases the excavated body collapses under t superincumbent weight and acute symptoms are brought on which may include weakne pain in the legs and paraplegia. X radiation is the treatment of choice and the resul are good.

Boxer Clark and Davis record a case which was treated with radium and 5 yea afterwards showed no sign of recurrence. They analyse 27 cases recorded in t literature.

Sarcoma. Sarcomata of the vertebræ may be indicated on the radiograph by increased density or by localised erosion of the bone The type showing increased dens *may also show massive tumour bone formation beyond the normal periphery of t* involved bones.

Breitlander describes an osteoplastic spindle-celled sarcoma of the fifth lumb vertebra in a boy aged 14 years. The radiographic illustrations show a dense structurele marble-like vertebra. Lipiodol was held up at the first lumbar vertebra, and at operatio a soft tumour was found in the spinal canal. The fifth lumbar vertebra was scleros on the periphery but hollowed out in the centre and filled with a mass of soft tissue

Erosion of the vertebræ due to sarcoma is most frequently seen in the young, a it has an appearance which can be considered as characteristic. The involved bo appears to be undergoing solution in some corrosive fluid, and if radiographs are tak at intervals the outlines of the involved vertebræ gradually disappear The erosi may begin at any point. Unlike tuberculous caries, in which *débris* of the destructi process remains to be shown on the radiograph, sarcoma makes a clean solution calcareous *débris* can be detected, and further it gives no evidence of abscess formatio The size of the sarcoma may be out of all proportion to the relatively trifling erosion the bone. In one case which occurred in my series, the tumour from the lumbar spi grew eventually to be as large as the boy's trunk.

In another case referred to the author a man of 30 years had a history of 6 montl of weakness of the legs and pains in the abdomen—whilst in hospital he developed complete paraplegia. Radiographs showed an ivory tenth dorsal vertebra which w found to be due to a spindle-celled sarcoma, the muscles of the back and the element of the neural arch were also involved.

Isolated ivory vertebræ are sometimes associated with some simple tumours withi the spinal canal—Lipoma Fibroma etc

Secondary sarcomata may be seen on radiographic examination of the thorax.

Carcinoma. One of the commonest sites for the development of metastases o *carcinoma is the spine. Radiographs may show that such lesions are confined to on* vertebra or that most of the bones of the vertebral column are involved

The radiographic appearance shows considerable variation in different cases. Th latent negative radiographic period may be of months duration during which th patient may complain of severe or wearing pain though the radiographs show no chang In some the carcinomatous deposits result in rounded areas of bone within the cancellou structure of the vertebral bodies which are either more dense or less dense than th

head to the anterior extremity the ribs in this condition may appear to commence with a slight concavity which straightens out and merges into convexity just beyond the tubercle the curvature changing again into the gradually expanding anterior extremity

The radiograph of the adult thorax with this condition shows a straight posterior segment of the rib directed upwards and outward At the tubercle the rib is bent at an acute angle and most of the body appears to be straightened out and directed downwards in the direction of the costo-phrenic angle

The angulation is most marked in the middle and lower ribs the first or second may be the only ones not exhibiting this deformity

In multiple chondroma, nodules of cartilage may be indicated by defects in the shape and ossification of the ribs Later densely calcified nodules may appear in the defects These have been mistaken for lesions within the pleural cavity Simple or branched osteomata may be seen in cases of **multiple exostoses**

Fracture of First Rib Considerable interest has been aroused by the discovery during mass radiography surveys, of many old fractures of the first rib The fracture unilateral or bilateral appears to be sustained during early adult life 17–20 years. Those fractures seen in adults over 20 years of age are healed or exhibit evidence of pseudarthrosis of considerable duration Though a few of these fractures have been discovered by radiography following recent trauma accompanied with signs and symptoms, by far the majority in the healing or healed stage are discovered accidentally by mass radiography and the patients have no local signs or symptoms and cannot account for the lesion

In a few cases the fragments do not unite—a **pseudarthrosis** is seen at the site. The facts that identical appearances are seen to follow definite trauma, that the characters of healing and resolution are identical, and that most are discovered accidentally indicates that these lesions are of little clinical significance The discomfort caused by the fracture apparently is not of sufficient severity to cause the patient to seek medical advice and the injury which caused it is readily forgotten with the disappearance of the signs. Pseudarthrosis of cervical ribs is not uncommon and it may be that these and the lesions of the first ribs are produced by the same factors which were present in the experimental animals used by *Müller* (see p 170).

Slipping Rib The articulation of the last rib and its vertebra may be so loose that displacement occurs when the patient bends over Pain may be caused by the slipping rib which is accompanied with a "click" to be felt by a finger pressed against the rib during bending and straightening

DISEASES OF CHILDHOOD

Rickets. In thi condition the anterior and to a lesser extent the posterior extremities may show expansion and cupping In the severe cases angulation of the ribs may be seen.

Scurvy Marked expansion of the anterior extremity is present

GENERALISED BONE DISEASES

Hyperparathyroidism. General rarefaction of the bones. Individual ribs may appear to be uniformly expanded and devoid of cancellous tissue—an appearance which is seen in the long bones of the extremities in this condition. Other ribs may show localised cystic changes

In **polycystic dysplasia** and **polyostotic fibrous dysplasia** characteristic lesions may be seen in one or more ribs which are elsewhere of normal density and structure

CHAPTER XIX

THE THORAX

OSSIFICATION OF THE COSTAL CARTILAGES

OSSIFICATION of the costal cartilages is very rarely seen before the age of 20 years. After this time the percentage of patients showing evidence of ossification increases with age, until at the age of 45 to 50 most will show extensive ossification. Isolated examples of very early or very late ossification are occasionally met with. The author has seen it in a youth of 20 and *Köhler* reports a case showing complete ossification at the age of 21 years, and another a man of 70 years, with arterio-sclerosis showing slight ossification only.

The process commences in the first rib as irregular vertical bands which gradually fuse, the costal and sternal extremities being the last to ossify a feature which may lead to a radiographic appearance simulating that of a fracture. In the lower costal cartilages small ovoid islands of calcium first appear on the lower border. These may be mistaken for gall-stones or renal stones. Gradually the process extends along the lower border; this is succeeded by ossification of the upper border and finally the whole cartilage is ossified.

Generally speaking the process begins earlier and progresses more rapidly in the male, a feature which is in contradistinction to the process of skeletal ossification which *is always more advanced in the female. It appears to occur at an earlier age in men* and women who suffer privation. Attempts have been made to estimate the degrees of arteriosclerosis from the stage of ossification of the costal cartilages, but the evidence of relationship is not established. The condition has been investigated by *Köhler, Ernst, Rist, Galley* and *Troeme*.

THE RIBS

Ossification. The primary ossific centre appears about the eighth week of fœtal life in the neighbourhood of the angle—the nucleus for the sixth or seventh ribs being the earliest to appear.

At birth ossification has extended throughout the greater part of the bodies of the ribs. From 10 years onward but usually about the sixteenth year of life a secondary centre appears for the head, and in the case of the upper six or seven ribs two additional centres, one for the articular surface and one for the non-articular surface of the tubercle.

These secondary centres unite with the body about the twenty fifth year.

Congenital Deformities. Congenital deformities consist of bifurcation of the anterior extremity or fusion with an adjacent rib or ribs just beyond the tubercles. The latter deformity is associated with multiple hemivertebræ of the dorsal spine and large gaps in the bony framework of the thorax. The characteristics of cervical and lumbar ribs are referred to in another chapter.

Developmental Abnormalities. In **Chondro-osteo-dystrophy** irregularity in the ossification of the head and tubercle leads to an expansion and cupping of the vertebral extremity.

In **Albers-Schönberg's Disease** the ribs are denser and thicker than normal but uniform in shape. No sign of viscera or soft tissue (including costal cartilages) is shown on the film taken to secure detail of bony structure, i.e. it is purely a skeletal radiograph.

In **Myositis Ossificans Progressiva** irregularly branched bands of bone are seen attached to the ribs. In the adult marked contraction of the thorax and scoliosis may be seen to result from fixation of these ossified bands.

Radiographs of the ribs of the infant in **Osteogenesis Imperfecta** show a club-shaped expansion of both extremities, and instead of the normal regular concavity from the

irregularities are best seen in the fourth to tenth ribs. The erosion is not present in all cases, and the defect in the shadow of the aortic arch may be the only departure from the normal oblique radiographic appearance. The descending aorta may not be visible The heart may appear to be of normal size and shape, it may show some hypertrophy of the left ventricle.

A number of excellent radiographs of this condition have been published by *Rallsback* and *Dock*. *H Gladnikoff* has given an account of 3 cases treated surgically

Fray refers to a case in which the erosion was not visible on the radiographs of the patient at 10 and 12 years, but was obvious at 17 years.

Laubry and *Heim de Balsac* have recorded similar though less extensive erosion of the ribs in disease of the aortic and mitral valves and in essential hypertension

In the so-called hour-glass tumours of the spinal canal, the extra-spinal portion of the tumour may cause a widening of the rib interspace and later erosion of the adjacent borders associated with which the radiographs may show the shadow of a tumour projecting from the mediastinal shadows (see also Fig 880)



Fig 417 Radiograph of the thorax showing a large chondroma of the anterior extremity of the second right rib.

Enlargement of the mediastinal shadows by Lymphadenoma and Lymphosarcoma may be associated with pressure erosion of a rib.

Malignant Tumours of the pleura or mediastinum may erode and invade the ribs

Tumours of the Ribs. Fibroma of a rib is usually attached to the region of the tubercle and grows into the bony thorax as a rounded tumour the radiographic appearance of which may be mistaken for a hydatid cyst

Chondroma of a rib is usually seen growing from the costo-chondral junction. The

Osteitis Deformans. The whole or part of one or more ribs may show the fibrous or sclerotic changes of Paget's disease Only one vertebra with its rib on either side may be affected.

Multiple Arthritis. Irregularity of varying degrees of severity of the upper costo-transverse articulations is frequently seen in long-standing cases of Still's Disease and *Rheumatoid Arthritis.*

Tuberculous Caries Tuberculous caries of the rib occurs in association with the so-called collar stud abscess and is indicated by localised rarefaction of the bones in which small ill-defined denser shadows of sequestra may be shown. Any of the types of lesion shown in Fig 62, A—D (pp 71 and 72) may be met with. Such lesions are best shown by taking the radiographs with the film placed in contact with the skin overlying the lesion and the rays projected through the thorax in such a direction as to prevent overlapping of other body shadows. A further radiograph with a slight alteration of the angle of projection may yield additional evidence as will a radiograph taken with the central ray forming a tangent to the diseased focus the film being at right angles to the ray

In some cases of tuberculous caries of the spine with a paravertebral abscess the ribs included may be eroded (see Fig 405)

A number of cases of Sporotrichosis have been recorded in which foci have been discovered in the ribs (Sporotrichosis Costarum) by radiographic examination. The radiographs show areas of erosion in some ribs and cyst like expansions in others. In some cases the radiographs have appearances very like those seen in tuberculosis (see pp 71 and 72).

Illustrations of these are to be seen in the papers by *Zeitlin, Aimes* and *Altschul.*[1] *Carter* has published radiographs showing similar changes in Coccidioidal Granuloma

Erosion of the Ribs. Erosion of the ribs occurs as the result of pressure from an aneurysm dilated arteries in coarctation of the aorta tuberculous abscess from spine

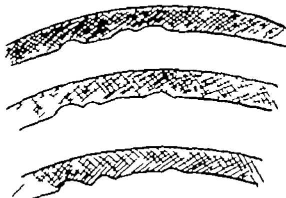


FIG. 416. Tracing of radiograph of ribs showing erosion of the lower borders by pressure from enlarged intercostal vessels in a case of coarctation of the aorta.

hydatid cysts tumours. The erosion of the ribs in coarctation of the aorta (Roesler's Sign) is a very valuable aid in the diagnosis. It has been recorded by *Neuhauser* in an infant 10 months old. With this congenital deformity the enlarged compensating intercostal arteries erode small concavities into the lower borders of the ribs. One or more such shallow excavations may be seen on each rib the most marked appear to be directly above or below similar depressions in adjacent ribs (see Fig 410). These

septa could be seen The condition was diagnosed on the radiographic appearance as a hæmangioma The patient was seen at intervals during the following year but no definite alteration could be detected in the size of the tumour He died shortly after this of acute lobar pneumonia. At post mortem examination, apart from the pneumonia and the rib tumour which were not associated with one another no other lesion could be found. A radiograph of the resected ribs is shown in Fig 418 Small deposits are also shown in adjacent ribs.

Harrell Wilson reported on microscopic examination that the lesion was a malignant hæmangio-endothelioma.

Sarcoma These malignant tumours may arise from any part of the rib. As the



Fig. 419 Radiograph of the thorax of a girl aged 20 showing an opacity with a convex inner border on a plane with the anterior extremity of the third and fourth ribs and the posterior surface of the seventh and eighth ribs. Sarcoma of rib.

tumour grows it projects as a rounded mass into the bony thorax. The following *details* of a case will illustrate the difficulty one may be faced with in diagnosis.

The patient a nurse about 20 years of age complained of pain on the left side of the chest. She gave a history of attacks of pleurisy in previous years. This factor a temperature chart which suggested a focus of sepsis, and the radiographic appearances (see Fig 419) led to the diagnosis of a localised empyema. With rest in bed the pain disappeared the temperature subsided, and the shadow diminished and the patient was allowed to do her duties. Several bouts of this nature occurred, but on each occasion the radiograph suggested a slight increase in the size of the shadow Unsuccessful attempts were made to needle the opaque body Eventually the diagnosis was altered to that of tumour and the rib was resected and the mass found to be a sarcoma. The patient died about 2 months after the operation

tumour is shown on the radiograph as an expansion of the anterior extremity of the rib. *This expanded extremity has an appearance somewhat resembling that of an* osteoclastoma. The walls which show calcification appear to contain calcified septa (see Fig 417) In some cases such tumours may reach a very large size

Multiple Chondromata of the ribs may be seen in cases of *Ollier's* type of chondrodystrophy (see Fig 120)

Hydatid Cysts within two of the lower right ribs were discovered by the cystic appearance of the bone in the radiographs of one of the author's cases. In *Meyer's* case the expansion of the first rib by the development of echinococcal cysts led to Klumpke's type of paralysis of the lower arm. His radiograph shows the cystic appearance of the rib

Osteoma. Large and long irregularly branched spurs of ossified tissue of the density of normal bone may be seen attached to the ribs in cases of myositis ossificans progressiva.

Multiple Exostoses of all the limb bones including the scapula, clavicle and pelvis, have been seen in a number of cases in which no evidence of rib exostoses could be



Fig 418. Radiograph f resected ribs (post-mortem) showing large honeycombed m th rib with multiple areas of rarefaction in the adjacent ribs. Histology malignant haemangio-endothelioma.

obtained, but in a boy aged 0 years the anterior extremities of the ribs showed club-like expansions Isolated simple or branched osteomata may be found.

Angioma. Angioma of the rib produces a radiographic appearance similar to that of the fibrous type of osteitis deformans in which the cancellous structure appears much coarser than the normal but the area involved is much expanded.

Osteoclastoma. In the early stages of this tumour the radiographic appearance may *simulate tuberculous caries. L. M Hilt has published the radiographs of a case.*

A Haemangio-endothelioma was seen in a man 60 years of age. On the clinical examination a markedly pulsating tumour was felt and the diagnosis of aneurysm was suggested. The radiographs showed a marked expansion of the ninth left rib in which multiple dense

side of the mid line which fuse during the second month of fœtal life They may fail to fuse (see Fig 421) Ossific centres begin to appear in this cartilage about the sixth month of fœtal life The first is that of the manubrium, and this is followed by the nucleus of the second third and fourth pieces during the interval before birth A nucleus of the xiphoid appears about the age of 3 years.

These segments appear on the radiograph as distinct bones separated by a narrow strip of cartilage until about puberty The separate segments of the body fuse with

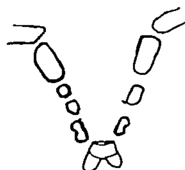


Fig 421

one another at about 28 years of age The manubrium remains as a separate bone usually throughout life. Direct lateral and semi-oblique postero-anterior radiographs with the shoulders pressed back should always be taken in cases of suspected sternal lesions.

Gummata and Tuberculous Caries are the most common inflammatory lesions of the sternum. It may not be possible to distinguish between them on radiographic appearances.

G Wachner has illustrated marked destruction of the manubrium within 2 months by Hodgkin's disease

Two cases of osteochondritis involving the manubrio-sternal junction have been seen

Erosion of the sternum by aneurysm or neoplasm will be best shown on the lateral radiograph, taken with the arms folded behind the back.

Löw Beer[1] has described and illustrated many pathological conditions of the sternum, including Osteomyelitis, Tuberculosis, Syphilis, erosion due to Aneurysm and Hydatid Cyst, Chondroma, Sarcoma and Hæmangioma.

Swenson has illustrated 2 cases showing anomalies of the ossification of the sternum.

E Kewesch illustrated the unusual development shown in Fig 421 in a Russian subject aged 45 years *H Morris* has published radiographs illustrating two suprasternal ossicles

Myelomatosis. Sternal puncture has revealed evidence of this condition in cases which show general osteoporosis but no circumscribed areas of destruction.

Similar opacities more frequent in the region of the first second and third ribs, may be due to extra pleura abscesses

Attention has already been drawn to the importance of screening the chest for secondary sarcomata prior to operative treatment of sarcoma of bone. The diagnosis of such secondaries will usually contraindicate amputation (see Fig 420).



FIG. 420. Radiograph of the thorax showing multiple secondary sarcomata

Multiple Myelomata. The ribs and the pelvis show the distinctive appearances of this condition better perhaps than the other bones.

The radiograph shows multiple rounded areas of rarefaction, about the size of peas when first seen, scattered throughout the structure of all the ribs. The diagnosis is confirmed by the finding of *Bence-Jones* albumose in the urine.

Altschul [1] has pointed out the similarity of the radiographic appearance of Multiple Myelomata and Sporotrichosis.

Carcinoma. Appearances similar to those described under multiple myeloma may be seen in the ribs as the result of metastases of carcinoma

In other cases sections of rib show localised erosion or sclerosis usually in association with typical changes in the vertebræ.

Pleural Effusions. In any case in which a pleural effusion or other opacity obscures the detail structure of the ribs adjacent radiographs should be taken using greater penetration to show the rib structure They may give a clue to the diagnosis.

THE STERNUM

Ossification. The sternum is ossified from two cartilaginous plates, one on either

can be placed. Such radiographs, with records of the angles of projection, will be the best key for the interpretation of subsequent radiographs taken of patients in these positions, and they will supply him with evidence to be obtained in no other way. By adopting this procedure the radiologist will appreciate that the slightest alteration of the angulation of the central X ray to the patient's head will obscure or bring into relief structures he seeks to demonstrate.

It must, of course, be remembered that an infinite variation in detail exists in the structure, shape and size of every part of the skull. Considerable asymmetry in development and form may exist, a fact which must be considered when assessing the appearances of the two sides, which should always be done.

To attempt to classify or describe the infinite variations of the normal in the shape, size and disposition, on one or both sides, of the accessory nasal sinuses, air cells, vascular channels, diploic spaces and bony texture would necessitate a volume to itself and yet it would be confusing, for it could only deal with the material examined. An equal amount of material at a later date or from another area would supply still further variation. Taken as a whole, then, we can regard the radiographs of the skull as the best medium we have for identification of the individual. The works of *M. Maresh* and *K. Lindblom* provide striking evidence of the futility of trying to establish a single norm at any given age.

RADIOGRAPHIC APPEARANCES

(1) **Lateral Radiograph.** The radiograph Fig. 422 will show the contour of the bones of the head, the thickness of the skull, the alignment and relative position of the parts. At the anterior extremity we see the frontal sinus, posterior to this the floor of the anterior fossa ending in the internal projection of the frontal bone where it articulates with the sphenoid. This thickening of the postero-inferior angle of the frontal and its articulation with the sphenoid casts a triangular shadow the apex of which is directed towards the vertex, and its concave posterior border is frequently mistaken by the untrained observer for the anterior border of the sella turcica. The sella turcica presents considerable variation in shape and size in apparently normal individuals. It appears as a slightly ovoid structure, with its diaphragmatic area opened and its long axis directed to a point just anterior to the bregma. The gap at the roof, *i.e.*, the space between the anterior and the posterior clinoid processes, may appear to be completely obliterated by fusion of the extremities. It will be seen from examination of the macerated specimen that even when this occurs an ovoid aperture about 0·7 by 0·3 inch covered by a membrane is left in the roof of the fossa. Radiographs which are taken in a slightly oblique plane may so project the shadows of the clinoid processes that the fossa appears to be obliterated or completely roofed in.

Beneath the sella turcica the sphenoidal sinus can be seen. The extent and size of this sinus is also variable. It may appear as an ovoid cavity, the posterior border of which does not pass beyond the anterior wall of the sella, or it may extend beneath the dorsum sellæ leaving a thin bony wall only to separate it from the floor of the sella. Immediately behind the dorsum sellæ are the dense shadows of the superimposed petrous portion of the temporal bones, with their well-defined superior margin marking the posterior border of the floor of the middle fossa. Within this dense shadow a light ovoid cavity may be seen; it indicates the auditory meatus. With suitable projections within the meatus single or multiple exostoses of different sizes may be found at all ages. They are more common in the female, may be bilateral and may occlude the meatus. The postero-inferior extremity of this dense shadow borders on the cellular structure of the mastoid.

CHAPTER XX

THE HEAD

Ossification. The bones of the head begin to ossify during the second month of foetal life, but it is not until the third month that the ossification has reached a stage at which it is possible to show evidence of bony nuclei by radiography of the pregnant mother. The squamous portions of the bones of the vault are ossified in membrane and the basal bones in cartilage. Detailed evidence of the number of nuclei and the times of appearance cannot be obtained by radiography of the living foetus. For details of ossification at birth, see pp. 1–4

There are many variations in the shape of the skull but they may be classed into three groups (1) brachycephalic, (2) mesocephalic and (3) dolichocephalic. The cephalic index can be determined by the use of the formula devised by *Retzius*

$$I = \frac{\textit{Greatest internal breadth in centimetres} \times 100}{\textit{Greatest internal length in centimetres}}$$

Brachycephalic when I = more than 80
Mesocephalic I = between 70–80
Dolichocephalic I = less than 70

Radiographic Technique. Radiography of the skull can supply essential evidence of osseous defects, deformity and disease, as well as evidence of intracranial lesions. Such evidence may in certain cases be supplied by radiographs taken in standard positions such as (1) true lateral, (2) postero-anterior with the forehead and nose resting on the film, the external auditory meatus and the outer canthus of the eye being in a line at right angles to the film and parallel with the central X ray (3) the postero-anterior with the nose and chin resting on the film, the external auditory meatus and the outer angle of the orbit being in a line which is at an angle of 40° with the X ray film and an angle of 53 with the central X ray. The two latter positions can readily be adjusted by means of a single right angled triangle made out of stiff material such as card, celluloid or metal, the longer side of the right angle resting on the radiographic film.

These radiographs must be supplemented by others taken with the patient, film and X ray tube so arranged that the shadows of structures liable to obscure are projected away from the area under investigation. In certain cases stereoscopic radiographs in several planes may be invaluable. These special radiographs are best taken without the Potter Bucky Diaphragm, and using a narrow cone which is directed towards the area to be investigated.

Many radiologists have devised technique and apparatus for the demonstration of different structures. Details of the most important will be found in the excellent book by *H K Pancoast F P Pendergrass* and *J P Schaeffer*. Mastoid and petrous portion of the temporal bone. *Collin Cottenot* and *Fidon Granger Haas Herrnheiser Löw Beer*[1] *Lysholm Martin*[1] *E G Mayer*[1] *Ratti Richter Schüller Sonnenkalb Stauning Stenvers Towne Worms* and *Bretton*

Sinuses. *Allen Chaumet Hirtz, Hodgson F C Mayer*[1] *Mühlmann Pfahler Wirth*

Optic canal. *Goalwin*

Canalis nasolacrimalis. *Kopylow*

I am of the opinion that every radiologist would be well advised to study a macerated skull by radiographing it in many of the positions into which the head of the patient

Branched vessel channels run from the neighbourhood of the fronto-sphenoidal junction, the sella, and the posterior border of the shadow of the petrous bone towards the periphery. The overlapping of the shadows of these venous channels gives rise to the appearance which may be mistaken for a stellate fracture. The coronal and other sutures present a characteristic outline which should not lead to any misinterpretation, though these present a variable radiographic appearance. They may not be distinguishable in some individuals in the second or third decade, yet in some elderly persons



FIG. 423. Fronto-occipital radiograph of the head.

A. Mastoid cells.
B. Eminentia arcuata with semicircular canals.
C. Occipital bone.
D. Sagittal suture.
E. Foramen magnum.
F. Dorsum sellæ.
G. Porus acusticus.
H. Lambdoidal suture.
I. Dense bone surrounding osseous labyrinth.

their outline is clearly visible. Their margins may appear to be thickened for their density may be strongly contrasted with the other bone.

In the face the outline of the antra can often be indicated.

Fronto-occipital Radiograph. This radiograph (see Fig. 423) is taken with the cassette against the back of the patient's head in such a position that the foramen



FIG. 422. Lateral radiograph of the head.

A. Oral pharynx.
B. Maxillary antrum.
C. Eminentia articularis.
D. Zygoma.
E. Sphenoidal sinus.
F. Outlines of anterior wall of middle fossa.
G. Lateral wall of orbit.
H. Pituitary fossa with tuberculum sellæ and anterior clinoid processes.
 (1) Anterior clinoid process.
 (2) Posterior clinoid process.
 (3) Dorsum sellæ.
I. Cribriform plate.
J. Lesser wing of sphenoid.
K. Middle meningeal artery.
L. Frontal sinus.
M. Floor of anterior fossa.
N. Stippling of bone due to diploë (general).
O. Ossified coronal suture.
P. Bregma.
Q. Pacchionian depression.
R. Pineal body.
S. Calcification in choroid plexuses.
T. Venous lake.
U. Vascular channels.
V. Lambda depression.
W. Lambdoidal suture.
X. Eminentia arcuata.
Y. Sinus transversus.
Z. Occipital protuberance.
8. Posterior fossa.

The occipital protuberance may present varying degrees of prominence, from relatively slight thickening to the formation of a long distally directed spur of bone.

The styloid process may be seen as a sharp spur of bone from the antero-inferior border of the shadow of the mastoid process.

eminentia arcuata. The dense outline of the osseous labyrinth is shown in which varying details of the semicircular canals, vestibule and cochlea may be distinguished. It also affords an antero-posterior projection of the dorsum sellæ with the posterior clinoid processes. With the central ray directed from a more posterior point on the vertex the posterior arch of the atlas will be projected within the outline of the foramen magnum.

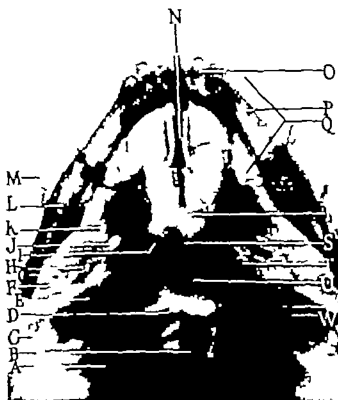


Fig. 425. Submento-vertical radiograph of the head.

A. Transverse process of atlas.
B. Odontoid.
C. Mastoid cells.
D. Anterior arch of atlas.
E. Carotid canal (external foramen).
F. Condyle of mandible.
G. Articular eminence.
H. Foramen spinosum.
I. Carotid canal (inner extremity).
J. Foramen ovale.
K. Lateral pterygoid plate.
L. Angle of mandible.
M. Coronoid process of mandible.
N. Septum.
O. Incisor and canine teeth in mandible.
P. Body of mandible.
Q. Maxillary antrum.
R. Sphenoidal sinus.
S. Dorsum sellæ and basi-sphenoid.
T. Apex of petrous bone.
U. Basi-occiput.
V. Porus acusticus.
W. Jugular foramen.

Postero-anterior radiograph with the nose and forehead against the film and the central ray directed vertically over the occipital protuberance the radiographic appearances shown in Fig. 424 will be obtained. This projection is most commonly used for examination of the maxillary antrums but its value as one of the routine series for investigating the head cannot be dispensed with.

The Submento-vertical radiograph (see Fig. 425) shows the relative positions and

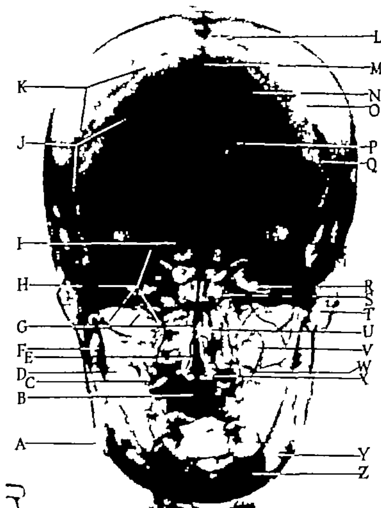


Fig. 121 Postero-anterior radiograph of the head

A Angle of mandible
B. Body of axis vertebra
C. Atlanto-axial joint.
D Transverse process of atlas.
E. Odontoid process.
F Malar bone.
G Nasal septum.
H. Orbit.
I Frontal sinus.
J Lambdoidal suture
K. *Coronal suture*
L. Sagittal suture
M Lambda
N Lambdoidal suture
O Coronal suture.
P Venous "lake" Diploic vessel
Q Lambdoidal suture.
R Auditory canal
S. Ethmoidal cells with roof of adjacent maxillary antrum
T Mastoid cell in tip.
U Nasal fossa with turbinate bones.
V Maxillary antrum.
W Floor of maxillary antrum.
X *Floor of nasal fossa.*
Y Inferior dental nerve canal in body of mandible
Z. Mental foramen.

magnum is in the centre of the film the head is flexed as much as possible and the central ray is directed through the sagittal line mid way between the frontal eminences towards the middle of the film. As indicated it shows the contours of the upper border of the petrous bone with the positions of the inner portion of the auditory canal and the

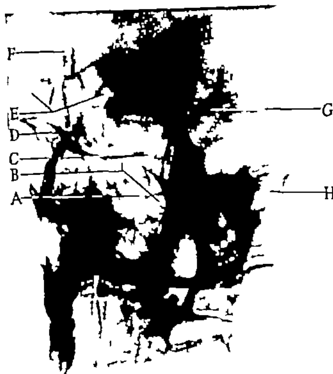


Fig. 427 Parieto-orbital radiograph of the head

A. Lower rim of orbit
B. Ethmoid cells.
C. Optic foramen.
D. Floor of anterior fossa
E. Frontal sinuses.
F. Coronal suture
G. The temporal line
H. Mastoid cells.



Fig. 428. Mastoid and temporo-mandibular joint

A. Body of mandible
B. Floor of maxillary antrum.
C. Anterior wall of middle fossa.
D. Anterior wall of middle fossa opposite side
E. Eminentia articularis.
F. Temporo-mandibular joint
G. External auditory meatus.
H. Tegmen tympani.
I. Mastoid cells.
J. Anterior wall of lateral sinus
L. Sinus plate
M. Lambdoidal suture

sizes of the structures at the base of the skull. It should not be obtained in cases where injury or disease of the cervical spine is suspected.

Postero-anterior radiograph with the closed mouth against the film and the central ray directed vertically through the occipital protuberance (see Fig 426) gives the best

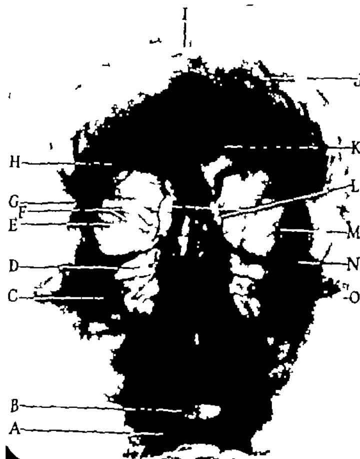


Fig. 426. Occipito-oral radiograph of the head

A. Body of mandible.
B. Occipital protuberance
C Petrosal bone
D Maxillary antrum.
E. Orbit
F Superior orbital fissure
G Zygomatico frontal suture
H. Roof of orbit
I Sagittal suture
J Convolution impressions on thin skull.
K. Frontal sinus (the opposite side has failed to develop).
L. Ethmoid cells.
M. Dense line due to end on projection of squamous temporal bone
N Zygoma.
O Zygomatic arch

general indication of the position and development of the frontal, ethmoidal and maxillary sinuses and an uninterrupted picture of the walls and contents of the orbits together with the details indicated in the legend.

Fig 427 which is taken with the rim of the orbit pressed against the film and the central ray directed vertically through the opposite parietal, shows the position of the optic canal and the ethmoid cells

premature synostosis of all or some of the bones, defects in ossification of the vault or base and anomalies of the articulations and form of the occipital bone and the atlas.

A number of theories have been put forward to account for premature synostosis of the bones of the skull, including intrauterine pressure, rickets and syphilis, but cases exist in which the cause cannot be ascribed to any of these factors Some cases show definite hereditary and familial distribution

Lacuna Skull (*Lückenschadel*) In this condition the skull shows a remarkably irregular ossification in which rounded thin, parchment like areas of bone are surrounded and connected with similar areas of varying sizes by thicker bony ridges—the whole presenting a net like appearance (see Fig 13). The changes are most marked in the parietal and frontal areas but the occipital bone may also be involved. Premature fusion of the sutures in this condition may be associated with microcephaly meningocele and occasionally encephalocele and spina bifida and though the majority succumb in infancy to these associated lesions, a few survive to adult life *T O Dorrance* has recorded an account of a boy who had none of these additional defects and had reached the age of 17 years

As indicated on p. 15 the condition has been identified by the author in the foetus in utero

The author has published the radiograph of an infant in which no ossification of the parietal bone had occurred at birth, and the account by *M Pellini* of a child 16½ months old illustrated an irregular band like defect in the ossification of the parietal bone

Premature Synostosis results in marked alteration in the general outline of the skull. Three fairly well-defined types are met with: turricephaly scaphocephaly and plagiocephaly

Turricephaly is the commonest type It is denoted by an abnormally high and thin skull in which the frontal bones are fused and present well-marked convolution impressions the so-called digital impressions There is usually compensating bulging of the area of the large fontanelle but no widening of the sutures or atrophy of the dorsum sellæ These cases may also be separated into two groups the Oxycephalic and the Microcephalic. The early fusion of the frontal bones and bones of the base is associated with deformities of the nose, jaw and teeth, and prominence of the eyes.

Though the whole skull is usually thin and marked by digital impressions and deepening of the pacchionian excavations, cases have been reported in which the deformity is associated with hyperostosis (see Fig 450)

The chief symptoms are defective vision and headache often noticed during the first 5 years of life Papillœdema may be followed by optic atrophy The pressure of the cerebro-spinal fluid may be raised. Decompression in the early stages offers the best results.

W Sheldon has illustrated an article with radiographs of the skulls of a mother her two boys and a girl, all of which show oxycephaly

Some alteration in the form of the skull may be produced by long-continued pressure on hard pillows or during hyperextension on a Bradford frame.

Scaphocephaly is the term applied to skulls which have a long antero-posterior diameter and are small in size This type of deformed skull is seen in some cretins In a cretin of 6 years the antero-posterior diameter was twice the length of the vertical measurement between the vertex and the upper border of the petrous bones.

Plagiocephaly is an asymmetrical form of craniostenosis which results from an irregular synostosis of the bones The limitation of the growth of that part of the skull in which synostosis occurs is seen in marked contrast to the compensating overgrowth and bulging of the segments which have not fused.

Fig 428 shows the details of the temporo-mandibular joint and the structure of the mastoids.

The variations in the appearances of the structures shown with the different projections illustrated in Figs 422–428 emphasises the need for these special projections when the clinical indications point to one or more structures and each has its usefulness but to use all as a routine would be unjustifiable. Generally speaking the more careful the clinical examination the clearer the indication given to the radiologist as to the structure or structures involved. When intracranial lesions are suspected, the projections shown in Figs 422–427 would be considered reasonable in the first instance

The borders of the foramen magnum and the posterior arch of the atlas may be



FIG 429 Radiograph showing (1) the foramen magnum and (2) the posterior arch of the atlas. The film is placed against the occiput and upper part of the neck. The neck is flexed to its fullest extent and the central ray is directed from the vertex towards the foramen magnum.

obtained by placing a film against the occiput and neck with the neck flexed to its fullest extent and the rays directed from the vertex towards the occipital protuberance as in Fig 429

CONGENITAL DEFORMITIES

Gross deformities of the skull such as Acrania, Anencephalus and Hydrocephalus, which are incompatible with life, can be detected by radiography of the foetus in utero during the last few months of pregnancy (see pp 11–15 Also Figs 9 10 12 A and B 18)

The importance of detecting these gross deformities at the earliest possible date and the consequent termination of the pregnancy while the foetus is still small cannot be too strongly emphasised

The value of radiography to the obstetrician in the discovery of such deformities and in showing the relative size and position of the foetal head to the maternal pelvis warrants its more frequent application in obstetrics.

Numerous radiographs demonstrating these congenital foetal deformities have been published in the literature

A series of radiographs illustrating vertex breech, and transverse presentations, twins, triplets, hydrocephalus and anencephalus is published in the paper by *Grunspan de Brancas*

The relative sizes of the foetal head and maternal pelvis can be measured by the techniques devised by *Rowden and Thoms* A simple efficient and rapid method has been described by *V Reece*

Pfalz has published a radiograph showing four foetuses in the uterus

The congenital deformities of the skull which are compatible with life consist of

premature synostosis of all or some of the bones defects in ossification of the vault or base and anomalies of the articulations and form of the occipital bone and the atlas

A number of theories have been put forward to account for premature synostosis of the bones of the skull, including intrauterine pressure rickets, and syphilis, but cases exist in which the cause cannot be ascribed to any of these factors Some cases show definite hereditary and familial distribution

Lacuna Skull (*Lückenshadel*) In this condition the skull shows a remarkably irregular ossification in which rounded thin, parchment like areas of bone are surrounded and connected with similar areas of varying sizes by thicker bony ridges—the whole presenting a net-like appearance (see Fig 13). The changes are most marked in the parietal and frontal areas but the occipital bone may also be involved. Premature fusion of the sutures in this condition may be associated with microcephaly meningocele and occasionally encephalocele and spina bifida and though the majority succumb in infancy to these associated lesions, a few survive to adult life *T O Dorrance* has recorded an account of a boy who had none of these additional defects and had reached the age of 17 years

As indicated on p 15 the condition has been identified by the author in the foetus in utero

The author has published the radiograph of an infant in which no ossification of the parietal bone had occurred at birth, and the account by *M Pellini* of a child 16½ months old illustrated an irregular band like defect in the ossification of the parietal bone.

Premature Synostosis results in marked alteration in the general outline of the skull. Three fairly well-defined types are met with: turricephaly scaphocephaly and plagiocephaly

Turricephaly is the commonest type It is denoted by an abnormally high and thin skull in which the frontal bones are fused and present well-marked convolution impressions the so-called digital impressions There is usually compensating bulging of the area of the large fontanelle but no widening of the sutures or atrophy of the dorsum sellæ These cases may also be separated into two groups, the **Oxycephalic** and the **Microcephalic.** The early fusion of the frontal bones and bones of the base is associated with deformities of the nose jaw and teeth, and prominence of the eyes.

Though the whole skull is usually thin and marked by digital impressions and deepening of the pacchionian excavations, cases have been reported in which the deformity is associated with hyperostosis (see Fig 430)

The chief symptoms are defective vision and headache often noticed during the first 5 years of life Papillœdema may be followed by optic atrophy The pressure of the cerebro-spinal fluid may be raised. Decompression in the early stages offers the best results.

W Sheldon has illustrated an article with radiographs of the skulls of a mother her two boys and a girl, all of which show oxycephaly

Some alteration in the form of the skull may be produced by long-continued pressure on hard pillows or during hyperextension on a Bradford frame.

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The Microcephalic skull is seen as a separate entity or in association with a dwarf body The brain in these cases may be very small. In some the convolutions are small and diminished in number while in others cyst like cavities which communicate with

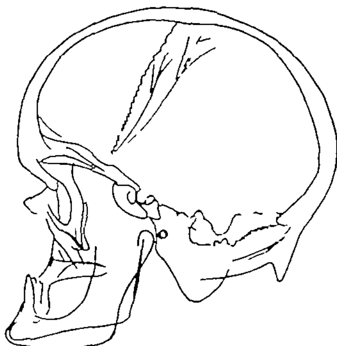


FIG. 431 Tracing of lateral radiograph of the skull of patient with achondroplasia. Note the shortness of the base the depression of the facial bones, and the projection of the mandible (*Graham s skeleton*, 40 years of age).

the sub-arachnoid are found in the cortex The small dimensions of the skull may be uniform or may be associated with irregular conformation as in the types of turricephaly Other types exist in which the facial bones are relatively normal but the crania small In 1 case in the author s series the radiographs of a microcephalic child, aged 2 years showed a marked sclerosis and upper projection of the floor of the anterior and middle fossæ which had a convex upper outline

Achondroplasia. In this condition the bones at the base of the skull show premature fusion, while the bones of the vault bulge to accommodate the growing brain. The premature fusion of the base leads to a characteristic appearance of the face (see Fig 431) and when associated with irregular development of the occipito-atlantoid elements and the formation of transitional vertebræ the additional signs of platybasia may develop (see pp. 478–9)

DEFECTS IN OSSIFICATION

Holes in the Skull. In the parietal bone on one or both sides of the sagittal suture about 1 inch anterior to the lambda a small foramen for an emissary vein and sometimes a small artery will be seen. In the majority of cases this is only large enough to admit an ordinary pin but in other cases the hole or holes may reach the size of 1 inch diameter they may approximate and communicate with one another with a breach of varying extent, presenting then a binocular appearance The combined hole may then measure 2–3 inches across. These larger parietal holes are often found in the members of several

Premature fusion of the frontal bones produces a deformity known as Trigonocephaly in which the anterior part of the skull is keel-shaped and the anterior fossa with the orbits and the ethmoid bones is compressed, with a compensating increase in the dimensions of the posterior elements. Digital impressions are sometimes well marked. This deformity of the fœtal head may lead to difficulties in labour.



Fig. 430. Marked "digital" impressions in a case of premature synostosis of the skull. Girl aged 14 years. A similar appearance is seen in ependymitis.

Pesme refers to a condition called Hereditary Cranio-facial Dysostosis which was first described by *Crouzon* in 1912. It presents three cardinal signs: (1) cranial malformation, (2) facial deformity, (3) ocular disturbances. He described the appearance of a girl of 4 who had an oxycephalic cranium, a marked atrophy of the maxillæ with atresia of the nasal fossæ and a parrot beak-shaped nose and a very marked exophthalmos. The radiographs show a dome-shaped malformation of the vault with obliteration of the osseous sutures, a very thin skull, sinking in of the middle fossa and a nearly vertical orientation of the sella. As the exophthalmos increased, optic atrophy was produced.

Greig [1] described the condition of Hypertelorism in which there are (1) deep round orbits which are wide apart, (2) massive mastoid processes, (3) short nasal bones, (4) sphenoids with large fossæ and lesser wings with retarded greater wings, (5) prominent vertex with low forehead.

circumscribed absorption, probably due to pulsation, is seen in some infants to follow injury to the skull. Meningocele or encephalocele in which the outer borders may be flanged mucocele dysostosis syphilis; tuberculous erosion by presence of neoplasm localised destruction by secondary neoplasm cholesteatoma and pacchionian erosion produce a similar appearance an account of which will be found by reference to index

Failure in the ossification of the bones of the skull is most commonly seen in associa



FIG 432B. Lateral radiograph of the same patient as Fig 432A. Note the multiple Wormian bones. Cranio-cleido-dysostosis.

tion with hernia of the brain or meninges. The latter may be large yet be unrecognisable in the fœtus in utero (see p. 15). The most common sites for these defects are the occiput and the floor of the anterior and middle fossæ In the occipital bone the defects, which are commonly in the mid line can be shown on radiographs as round or ovoid holes These may appear on the lateral radiograph to be surrounded by an outer flange. In the base the chief locations for these localised defects are in the roof or angle of the orbit, the root of the nose or in the region of the sella. The defect in the frontal bone may be mistaken for a development of the frontal sinus A mucocele can produce a similar clear-cut destruction in this area. In the meningocele the defect may be *small* in comparison with the size of the hernial protrusion. The size of the skull is to some extent dependent upon the amount of brain which occupies the hernial protrusion. In some cases premature fusion is associated with the defect, and the hernia in such

generations of a family Thus H M *Goldsmith* examined 50 members of the Catlin family distributed over five generations Sixteen exhibited the defects 3 were women, 13 were men. The lesions came to be known as 'the Catlin mark. *Grieg Pepper* and *Penderglass Irwin* and *Taylor* have recorded similar familial lesions In the young patient pulsation may be felt at the holes but with age these tend to diminish in size In the members of some families radiographs show large ovoid defects in the parietal



FIG. 422A. Defective ossification of the skull in cranio-cleido-dysostosis. Both clavicles and femoral necks also showed defective ossification.

bones between the eminence and the sagittal suture These defects may measure 4 × 8 cm. They are indicated by bilateral depressions due to failure of ossification of the outer table The margins of the defects are shelving : the bases may be devoid of bone or the latter may be reduced to the thickness of parchment

The positions of these hereditary defects establish their identity Other holes may be due to such lesions as Schüller s disease trephine or traumatic holes Gradual

Besides these acquired forms of basilar impression we have the deformities of the transitional vertebræ at the occipito-atlantoid junction. Such deformities are common. Some may result in displacement of the head in one or other direction and because of this and the abnormal form of the transitional vertebral processes which are often asymmetrically developed, the foramen magnum may be encroached upon and pressure exerted upon the structures which transverse or are closely associated with it The signs and symptoms produced so resemble the acquired forms that both acquired and developmental forms are usually referred to as Platybasia When these transitional forms of vertebræ occur in association with premature fusion of the bones forming the base of the skull, as in Achondroplasia and Arachnodactyly serious occlusion of the foramen may result

W T Peyton and *H O Peterson* have made a valuable contribution to our knowledge of basilar impression, in which they include an account with drawing, showing the nature of the deformity in the more important cases which have been published. They believe that it is due to a developmental defect and there is a variable degree of fusion of the atlas with the occipital bone in these cases Certainly defects in the posterior arch of the atlas are common The term " manifestation of an occipital vertebra " was used by *Kollman* in cases where the appearance suggested fusion with the occipital bone. As with other junctions in the spinal column certain vertebræ on either side may show characters of the column above or below When the shift is away from the head it is referred to as " atlas assimilation," when towards the head as " manifestations of an occipital vertebra." The most constant and reliable differential features between the two conditions are —

The joint surfaces on the pro-atlas, like those of the normal occipital bone, are so placed that if the planes of these surfaces were projected they would converge caudalward, while the joint surfaces of the assimilated atlas are placed like the normal superior articular surface of the altas and if projected converge cranialwards.

Further in assimilation of the atlas there is almost always a foramen on each side between the posterior arch of the fused atlas and the occipital bone for the passage of the vertebral artery and the cervical nerves are in their normal relationship to the atlas and the base of the occipital bone

It is said that the posterior arch is never well developed in manifestations of an occipital vertebra. As with other development irregularities, they may be present for years without symptoms, but once they become apparent, appear to progress. Case reports suggest that it is often fatal. The patient appears to have a short neck, the head being low on the shoulders and tilted backward movements are restricted, and some muscular atrophy may be apparent.

The signs and symptoms present may include irritation and paralysis of the cervical nerves and spinal cord tracts due to compression at or near the foramen magnum irritation or paralysis of cranial nerves in the posterior fossa compression of the medulla oblongata by the odontoid process which projects through the foramen magnum into the posterior cranial fossa cerebellar disturbances due to compression of the cerebellum in a shallow posterior fossa increase in the intracranial pressure. There may be associated hydrocephalus.

Surgical treatment is designed to decompress the posterior fossa and relieve the pressure in the upper cervical area.

Other contributions which the student is advised to study are those by *A Bystrom*, *L. Bolk* *W E. Chamberlain* and *I Schüller*

In *Congenital Hydrocephalus* the sutures are widened, permitting the roof and sides of the skull to be pushed out. The base is flattened. The sella turcica is widened and

cases may be as large as the skull. The condition is frequently associated with hydrocephalus, spina bifida and deformities of the extremities. The meningocele may be distinguished from the encephalocele by the injection of air into the hernial protrusion, for the latter communicates with the ventricles.

In the condition known as **Cranio-cleido Dysostosis** defective ossification is seen in large areas of the skull, in the middle thirds of the clavicles, the femoral necks, the pelvis, and the scapulae. The bones of the hand show a characteristic shape. The deformity may be present in several members of one family and appears to show hereditary distribution in some cases. The radiographs of the skull in these cases may show large areas not ossified, failure of fusion at the fontanelles and sutures, and the presence of multiple Wormian bones (see Figs. 482 A and B). In the newly born the defects in ossification may be larger than the ossified segments. With increasing age ossification spreads, other multiple islands of bone appear and gradually the borders come together and are united at irregular sutures. The deciduous teeth may be retained and the permanent teeth may be correspondingly delayed in eruption. The bones of the base of the skull and of the face are small, also the sinuses, and the eminences of the skull may be unduly prominent. The jaws are often prognathous.

Further details of the condition are given in the general account, see p. 377

Considerable variation occurs in the form and outline of the elements of the skull, as will be appreciated from the complexity of the outlines of the Wormian bones in Figs. 482 A and B. The irregular outlines of accessory islands of bone must not be mistaken for fractures. The visibility of sutures is also very variable. The metopic suture between the frontal bones may persist, in which case the frontal sinus does not cross it.

Basilar Impression (Platybasia). As the result of plasticity of the bones of the skull, notably in such conditions as **Osteogenesis Imperfecta, Rickets** particularly **Renal Rickets Type B Hyperparathyroidism, Osteomalacia and Paget's disease**, the weight of the head pressing down upon the cervical spine causes the upper elements of the latter to encroach upon the foramen magnum and posterior fossa and compress the elements of the nervous system within. This may be accompanied by symptoms of irritation or paralysis of cranial and cervical nerves, cord tracts, medulla oblongata, cerebellum, as well as those due to increased intracranial pressure. In those cases with symptoms the lesions are often associated with hydrocephalus. Such symptoms have been mistaken for those of occipital neuralgia, syringo-bulbia, syringomyelia, disseminated sclerosis, cerebellar tumour. *Schüller* considers that the condition may be induced by the carrying of heavy weights on the head. The upward projection or posterior displacement of the odontoid into the foramen magnum may be detected by radiographs taken in the fronto-vertex projection and in the lateral radiograph by drawing a line from the posterior lip of the foramen magnum (not always an easy point to determine) to the posterior edge of the hard palate or by measurement of the basal angle as described by *Welcker*. The basal angle is defined as the angle subtended by a line drawn from the nasion to the tuberculum sellae, and a line drawn from the anterior margin of the foramen to the tuberculum sellae. This is usually somewhere in the region of 135 degrees; lesser measurements indicate degrees of the kyphotic base, greater measurements the extent of platybasia. Some variations in either directions to as much as 10 per cent. may occur as a result of certain dystrophies and metabolic disturbances in childhood. Associated with these you may also have alteration in the facial angle (normal about 75 degrees), as described by *Weisbach*. This is the angle at the chin formed by a line drawn from the nasion to the central point at the antero-inferior margin of the mandible and another from this point to the anterior margin of the foramen magnum. This angle is reduced in acromegaly, cretinism.

which is in contrast to the rarefied bone. In severe cases pressure deformity of the base occurs with upward displacement of the occipital bone and the base of the sphenoid, associated with a diminished vertical and an increased antero-posterior measurement of the cranium. (See Basilar Impression pp. 478–9.)

In rickets associated with renal or cœliac disease radiographs may show very marked irregularities in the ossification of the skull. Two types of changes are to be distinguished. In one rounded islands of denser bone, varying in size from a pin head to a sixpence, are seen scattered throughout the frontal, parietal, and squamous portions of the occipital bones. In the more severe cases these changes are also present in the *squamous portion of the temporal bones.*

Associated with these changes there may appear a large area of relative translucency



Fig. 433. Renal rickets, Type B. Note the multiple circumscribed islands of decalcification and the thickening of the skull. Youth aged 21 years.

at the vertex and in the occipital region, as well as a thin layer of new bone on the meningeal side of the inner plate of the frontal and parietal bones.

These appearances are somewhat similar to those seen in the skull which is affected with osteitis deformans.

In the other type of case the changes are associated with a more marked renal deficiency (Type B Renal Rickets). The radiographs of the skull show well-defined circular or ovoid areas of decalcification of varying size affecting all the bones of the skull and associated with very *marked thickening of the parietal bone* and of the occipital bone in the region of the protuberance. The outline of the inner table is well defined, but the outline of the outer table cannot be made out.

flattened. If some of the bones are prematurely synostosed an asymmetrical bulging of the skull occurs, with areas showing marked digital impressions and others, localised hyperostoses

In the condition known as Arachnodactyly irregularity in ossification leads to cranial and facial deformity the distance between the eyes is increased and the forehead is prominent and broadened

Anomalies in the occipito-atlantoid articulations are frequent. Complete or partial defects in the ossification of the posterior arch of the atlas are not infrequent. Fusion of the atlas to the occipital bone or to the axis, fusion of the odontoid to the atlas, unilateral occipitalisation of the atlas, and irregularities of the articulations are among the anomalies seen in this area

Radiographs of examples have been published by *Geipel, Gladstone* and *Wakeley R H Hunter Ingber Roger* and *Renander*[1] *Goldhamer* and *Schüller*

Irregularities at the atlanto-occipital junction may also be due to injury or disease. Measurements from the foramen magnum may be very difficult because of its irregular contour its borders may be raised or bent upwards. In addition the petrous may be pushed up and the angle of the clivus with the horizontal flattened out.

These deformities can be shown by the technique adopted for Figs 422 and 423, and by taking radiographs of the area through the mouth

DEVELOPMENTAL BONE CONDITIONS

Achondroplasia. Reference has been made in a previous paragraph to the premature synostosis *of the bones of the base of the skull, the compensating bulging of the* membranous bones of the vault and sides and the asymmetrical development of transitional vertebræ with the pressure effects due to occlusion of the foramen magnum.

Chondro-osteo-dystrophy In this condition the bones of the skull do not generally *show* any *definite departure from the normal but in a few faulty ossification of the* base may lead to an appearance simulating achondroplasia.

Radiographs of the skulls of several patients showing multiple exostoses of the limb bones, did not reveal any bony abnormality But in generalised chondromatosis *several foci may be seen.*

In the condition known as **Albers-Schonberg's Disease** the bones of the skull, particularly those at the base show very marked thickening and increase in density The outlines of the sinuses and individual bones become obliterated by the expanded dense bone. The foramina at the base appear to be greatly diminished. All the accessory sinuses and air cells in the cranial and facial bones may be completely filled in by this dense bone The sella turcica may also appear to be diminished in capacity

For **Osteogenesis Imperfecta**, see p. 486, and **Polyostotic Fibrous Dysplasia**, see pp 500–1

The changes in the skull in **Arachnodactyly Cranio-cleido-dysostosis** and **Cranio-facial Dysostosis** are referred to in a previous chapter

BONE DISEASES OF CHILDHOOD

Scurvy Associated with some degree *of general osteoporosis marked swelling of* the soft tissues over the skull may be shown. This is due to a subaponeurotic hæmorrhage. It may completely resolve or later show a deposit of calcium and ossification suggesting a flattened exostosis.

Rickets. *In this condition no changes may be evident on a radiograph of the skull.* For **Cranio Tabes** see p 19 In the severe degrees the bones of the head are rarefied, the parietals have a woolly appearance, and the denticles stand out with a density

into the cranium. The sinuses are all expanded. One or more cystic areas may be present in the osteoporotic skull.

Polycystic Dysplasia. Multilocular cysts in the skull of varying size may be associated with similar lesions in other bones.

Simple Cysts. These may represent the final stage of cephalhaematomata. These cystic lesions are not associated with the general osteoporosis of the skull as in hyperparathyroidism. They show the same characters as are illustrated in other sites.

Ehrlich[1] has described a case of circumscribed osteitis fibrosa of the skull in which no other lesion could be detected and no evidence of hyperparathyroidism could be found. The patient complained of headaches. The radiographs show the characteristic appearance of localised osteitis cystica—polycystic dysplasia—which appears to be confined to the parietal bone. The condition had existed from infancy.

Polyostotic Fibrous Dysplasia. In this condition the whole or a localised area of the facial or cranial bones may be markedly expanded, even 1–3 inches thick. The affected area has a ground glass-like appearance, little less than normal density, i.e. denser than the localised osteitis fibrosa cystica; the periphery regular; no internal cancellous detail. Other bones of the skeleton will show similar changes. The condition may be mistaken for leontiasis ossea in which the other parts of the skeleton are normal. In a generalised case investigated by the author the boy at 14 years had a skull which was over 1 inch thick. All the bones of the skeleton showed the changes illustrated in Fig. 63. This appearance was quite unlike the true leontiasis ossea (see pp. 408–9).

OSTEITIS DEFORMANS

Skull. In a number of patients in whom the characteristic changes of Paget's disease have been discovered in one or more bones of an extremity, radiographs of the skull will reveal no apparent change in the bony structure.

In others, depending apparently on the duration of the disease, a variety of appearances, diagrammatically shown in Fig. 435, may be encountered, and in my experience the sequence of changes appears to be as follows:—

(1) In the skull, with its inner and outer tables still well defined and of average thickness, ill-defined areas of relative osteoporosis may be detected. In some cases detection is possible only when the appearance is intensified by viewing the radiograph in an oblique position. On closer examination it may be difficult to define the outline of these areas. They appear to develop more obviously in the frontal areas, but they are not infrequent in the temporal and occipital zones. In some cases a wide osteoporotic zone, an inch or more in depth, may appear to run just beneath the outline of the inner table from the frontal area to the occiput. In other cases, osteoporosis of the skull is indicated by the relative density of a narrow strip of bone bordering the sutures.

A similar contrast is formed, particularly in the frontal area, by the relative decalcification of the supraorbital section of the frontal bone. These areas may eventually coalesce, in which case the osteoporosis may not be readily appreciated. Calcification of the pineal is a common accompaniment.

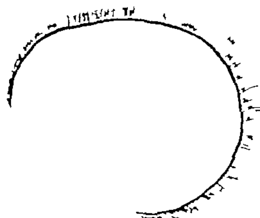
A large segment of the skull—I have observed this only in the frontal area once—may assume a general increase in density which tends to obscure the vascular and diploic markings; such areas appear more clearly defined than the osteoporotic zone.

(2) A fine stippled osteoporosis of the skull, associated with (a) the large osteoporotic areas previously described, though the latter are still less easily recognised, and (b) isolated rounded diffuse opacities, varying in size from an eighth to half-inch in diameter. The outline of the inner table, in such cases, may be difficult to make out. These appearances are the common finding in osteitis fibrosa cystica of hyperparathyroid origin, and this

Langmead and *Orr* found parathyroid hyperplasia in a case of renal rickets which presented radiographic appearances similar to those described under Type B renal rickets They suggest that while renal disease may produce the typical rachitic changes in bone, such changes in the skull as are illustrated in Fig 483 are due to osteoclastic resorption, the result of secondary parathyroid overactivity

A somewhat similar radiographic appearance is seen in *secondary carcinomata* and in some cases of osteomalacia.

Cooley has described and illustrated an unusual appearance of the bones of the skull in certain Splenomegalic Erythroblastic Anæmias of childhood. The condition appears to be confined to children of Mediterranean ancestry


FIG. 434 Tracing of radiograph of skull in Cooley's anæmia.

The affected children do not reach adult life. Microscopic examination of the blood reveals a very large number of erythroblasts in circulation they may outnumber the leucocytes The red corpuscle count is low 1½ to 3 million. The colour index is low The spleen is enlarged early in the disease. The affected children have a muddy yellow discoloration of the skin and the urine is dark and contains urobilin.

Radiographs of the skull show thickening of the inner and outer tables. The outline of the outer table may be obliterated The cancellous diploic bone is thickened, and closely packed striations resembling fine bony spicules are shown running perpendicular to the inner table In some cases the skull becomes four times thicker than normal. In the early cases *Cooley* describes a mottled appearance of the cancellous bone (see Fig 434).

Manderville has reviewed the literature and reported on the radiographic appearance of the skull in von Jaksch's Anæmia. He states that the cranium is thickened and the malar eminences are excessively prominent.

Vogt and *Diamond* have classified " congenital anemias " into three groups

(1) Congenital hæmolytic anæmia, which is associated with increased fragility of the red cells, acholuric jaundice, anæmia splenomegaly with remissions and exacerbations.

(2) Sickle-cell anæmia, which is associated with negro blood, familial tendency and the production of hæmolysis and jaundice.

(3) Erythroblastic Anæmia. Cooley's Anæmia, occurring in children of Mediterranean parentage and associated with severe anæmia, enlarged spleen and liver and large numbers of nucleated red cells in the circulating blood.

GENERAL BONE DISEASES OF ADULT LIFE

Osteitis Fibrosa Cystica Hyperparathyroidism. In this condition the radiograph of the skull may show a fine granular stippling of all the bone—small pin-head areas of density alternating with similar sized areas of rarefaction. The major portion of the outline of the inner and outer tables may be obliterated, particularly from the midfrontal to the parieto-occipital sutures. The outline of the sella turcica and other basal structures may be woolly and ill-defined and the basi-occiput may be pushed upward

Eventually this latter process extends throughout the whole of the cranium, so that it may become of uniform thickness. Often the process is most exaggerated in the frontal area, where the bone may reach a thickness of upwards of 2 inches. Serial examinations of skulls affected to this degree show that eventually the outer zone of osteoid becomes ossified, the process spreading from the periphery inwards. At one time, therefore the radiographs will show a clearly defined outer ossified border, then a zone of relative translucency and internally the irregular bossed dense zone. The



Fig. 436. Osteitis deformans (*Paget's disease*). Note the islands of dense bone in the rarefied matrix, the woolly outline of the skull, the large sinuses and the general thickening of the skull. Man aged 52 years.

definition of the subdural border is now difficult to define. The pathological changes follow in the base of the skull and the facial bones. The accessory nasal sinuses often appear to be markedly distended, but this is not invariable. The dura over the whole of the brain may become calcified.

By this stage the patient is frequently edentulous, but of those who still retain teeth the majority show marked dental sepsis.

Owing to the softening of the base of the skull, some degree of basi-occipital protrusion into the cranium is present.

Somewhat similar radiographic appearances of the skull are seen in young people with that type of Renal Rickets which is associated with hyperparathyroidism, referred to in this book as Type B.

Kasabach and *Gutman* have published an interesting paper on the relationship of Osteoporosis Circumscripta and Paget's disease, in which they illustrate the development of these areas of osteoporosis and the transition after several years into the characteristic woolly nodular appearance of Paget's disease.

probably accounts for the assumption by some writers that this and Paget's disease are merely variations of the one disease.

(3) The appearance of multiple opacities with woolly margins in a matrix of decalcified but thickened bone. These changes may be confined to one area of the skull,

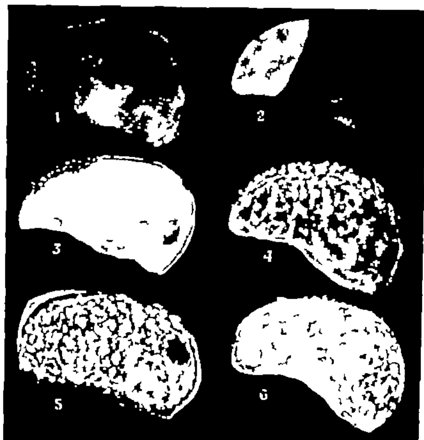


Fig. 435. Paget's disease of the skull.

(1) Osteoporosis circumscripta.
(2) Osteoporosis circumscripta associated with the appearance of increased density of frontal bone
(3) Osteoporotic zone in frontal area containing multiple dense island with woolly margins.
(4) Typical woolly skull of Paget' disease. Outer table of osteoid tissue
(5) Osteoid table undergoing ossification. Area of destruction in occipital area due to malignant metaplasia.
(6) *Malignant metaplasia of the subpericranial tissue in frontal area.*

the frontal being the first generally affected decalcified areas without the opacities may be present in the temporal or occipital areas.

In those sections of the skull presenting these appearances, the outline of the inner table remains clear but the outline of the outer table appears to be irregular and woolly. If, however the radiograph be examined with a strong light, the outline of the outer table will be seen quite clearly defined and separated from the irregular woolly outline of the dense nodosities by a zone of osteoid tissue. The detail of the diploë vascular channels, and suture lines are obliterated (see Fig. 430).

anterior mechanism, *e g.*, the pituitary and its connections to the tuberal region, might account for the diabetes insipidus.

In some cases attention is first drawn to the patient by a localised swelling on the head which is soft to palpation and a defect in the skull can be felt. A radiograph of the skull may show one or more rounded defects in an otherwise normally ossified



Fig 437 Tam-o'-shanter skull of osteogenesis imperfecta.

skull. The defects resemble trephine openings. If serial radiographs are taken at intervals of a month it will be seen that the "holes" increase in size. There is no evidence of any reaction in the bone adjacent to the defects, but the skull generally may later appear to be rather thinner than normal. Not only do the initial defects increase in size but other holes appear in the vertex or base, and eventually the whole of the skull may be decalcified by absorption of the intervening bone. With the increase in the bony changes diabetes insipidus and marked exophthalmos produce a clinical syndrome which is characteristic. Nevertheless the condition should be recognised in its early stages by the typical radiographic appearance of the skull, for in this stage the lesions appear to heal after X radiation. No more striking examples of 2 cases, one with and the other without treatment by X-radiation, have been seen than in the articles by *Frimann-Dahl* and *Forsberg* and that by *Sreuningsen*.

The radiation therapy in some cases has been followed by serious consequences (see p. 634).

Thickening of the skull due to von Recklinghausen's Neurofibromatosis may be mistaken for osteitis deformans (see Fig 450) (See also Syphilis of the Skull, p 502.)

Osteomalacia. In this condition the bones of the skull show osteoporosis and pressure deformities The latter are most marked in the atlanto-occipital area—the so-called basilar impression due to the upward thrust of the vertebral column into the softened skull

Hunter and *Turnbull* have recorded a case in which the radiographs of the skull show an appearance resembling the map-like skull seen in cases of Xanthomatosis and Type B Renal Rickets (see Fig 483) The patient was a woman of 83 who developed signs of osteomalacia after her fourth pregnancy The patient was given a diet of high calcium content, together with 15 grams of calcium lactate and two tablets of radiostol daily She became pregnant, but in spite of this the calcium diet improved her condition so that within three months the bone pain disappeared and she began to walk, and radiographs, taken six months after the first radiographs of the skull were taken, showed complete healing and obliteration of the localised areas of osteoporosis

Rariola has illustrated the radiographic appearance of the skull in senile atrophy He points out that there is a symmetrical depression of the parietal bones in old people between the sagittal suture and the parietal eminence. The radiographs show that these depressions are surrounded by haloes of rarefaction of the bone. They also show some increase in the size of the diploë and vessel channels, which appear much more marked than the normal.

Osteogenesis Imperfecta

The skull shows a considerable variation in the degree to which it is affected. In the fœtal type thin plates of ossified membrane may be found in the frontal, parietal and occipital areas with little or no ossification in the other cranial bones except at the base The cranium appears to be somewhat ballooned. In the infant the skull, except perhaps for a suggestion of delay in ossification, may appear to be normal in shape, but is obviously thin, and later it appears to be generally ballooned. As the patient advances in age the cranium appears to settle down over the base as if it was plastic and subjected to the weight of the brain this is perhaps most noticeable in the occipital area. It results in a comparative increase in the biparietal measurement and in a tam-o -shanter appearance of the cranium (see Fig 457) The less well marked cases which survive to adult life may show localised thinning and bulging of the cranium in the regions of the bregma and in the temporal and the occipital areas.

Xanthomatosis or Lipoid Granulomatosis. In 1915 *Schüller* described the radiographic appearance of multiple circumscribed decalcified areas in the skull as the map-like skull. Such appearances are seen in children presenting the additional features of exophthalmos and diabetes insipidus. Most of the cases described have been children in the age 1–5 year period (see also p. 632).

In 1919 Christian published an account of this condition in a girl aged 5 This child was apparently normal until 3 years of age when her teeth began to decay and the gums swelled. She had mumps at this age At 5½ years she developed excessive thirst and polyuria, drinking nine quarts of water per day The right eye became prominent then the left Radiographs of the skull showed an appearance which suggested numerous holes. Both tables of the skull appeared to be involved also the base, particularly in the region of the sella and supra-orbital plates.

Previously cases presenting similar clinical features had been described by Hand, Kay Pusey and Johnstone also Dietrich

The walls of the sella may appear to be destroyed and this involvement of the



FIG. 438B. R. W aged 13. The large area of the parietal bone is still thin at the site of the old lesion. Note absence of accessory nasal sinuses, see p. 488.



FIG. 439. Multiple circumscribed areas of decalcification of the skull due to metastases of carcinoma. Compare with Fig. 438A.

Gingivitis of a severe degree, foetid discharge from the ears, retarded growth are other clinical features which may be prominent. A boy aged 3 years, in whom the first sign of this disease appeared as a soft swelling in the temporal area when he was 16 months old, was brought to the author for X radiation treatment. Radiographs at this stage (see Fig 488 A) showed that most of the bone from one frontal bone had been decalcified and several other holes were also present in a thin skull. The base of the skull was decalcified except for the petrous portion of the temporal bone which had the appearance

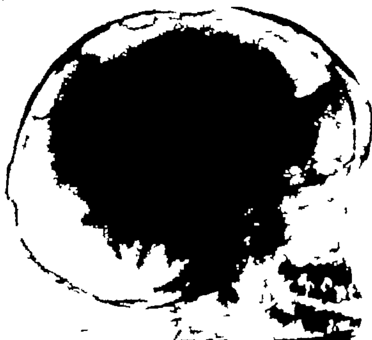


FIG. 488 A. *Schüller* map-like skull in a case of Xanthomatosis. Boy aged 3 years. Radiographic evidence of the disease had been present for 18 months previously

of a sequestrum. None of the other bones of the skeleton showed any defect. A most foetid discharge from both ears was present and the child presented marked bilateral exophthalmos, drank 6–8 quarts of water per day and had a corresponding polyuria. A grave prognosis had been given—the end was to be expected within 6 months. The foetid discharge from the ears readily ceased after a few applications of X rays, but the bones did not show any improvement under 1 year. Only small doses of so-called superficial X radiation was available. The boy has been kept under observation for over 10 years. The ossified areas of the cranium gradually acquired normal density, the small holes were filled and the large hole in the parietal has progressively diminished. Though pulsation can no longer be felt, radiographs show that there is still a large defect in the outer table. There is very striking absence of accessory nasal sinuses and air cells, the development of which seems to have been completely checked; only a few cells appear in the ethmoid. *His face is small in comparison with the normal size of his head.* He still has some proptosis and his general growth appears to have been somewhat diminished. He is of normal intelligence and now has less polyuria and polydypsia.

In some cases similar defects are to be demonstrated in the ribs pelvis, scapulæ and spine Cases have been reported in children aged 8–10 years. Microscopically the affected tissues show a lipoid cell hyperplasia of the reticulo-endothelial system, and because of this, it has been suggested that the condition is allied to *Gaucher's* splenomegalic anæmia and *Niemann* and *Pick's* lipoid-celled splenomegaly of infants

The condition is considered of long duration and benign in character

In certain cases which present similar radiographic appearances the typical foam cells are not found (see General Discussion p. 637).

Sosman and *Cignolini* have caused a disappearance of the skull defects by X radiation.

Illustrations of map-like skulls in xanthomatosis are given in the papers by *Frimann Dahl Lazareva Pickhan* and *Joel Lyon*[1] and *Marum Rothnem Weiss*[1 and 2] and *Rowland*

Radiographs of the skull in some cases of carcinoma metastases (see Fig 439) multiple myeloma (see Fig 440) renal rickets type B (see Fig 433) and osteomalacia present a somewhat similar appearance, but the age period will usually decide the diagnosis. Metastatic carcinomatous deposits in the bones of the skull have produced a syndrome similar to that described by Christian The defects in the skull have yielded to X radiation, but it is very doubtful if any of these adult cases are of the same nature as the infantile

An interesting series of radiographs by *Neville Crowe* with an account of a case showing bilateral ossification of the stylo-hyoid and other ligaments has been published by J B Cavanagh

The cure of a boy with multiple holes in the skull and changes in the proximal bones of the extremities is detailed on pp 634–7

An interesting case has been described by M B Redding A child of 21 months had a soft area 2 cm. in diameter in the left frontal area. The sella was normal. The teeth were normal. There was no exophthalmos nor polyuria. A positive von Pirquet test led to the diagnosis of tuberculous osteitis. No treatment was given. Later ulceration of the gums and loosening of the teeth were noted One and a half years later there was, in addition, exophthalmos (this became so gross that the eyes became infected and one had to be enucleated), a double chin and a protuberant abdomen. Within 6 weeks the skull erosion had markedly increased. Irregular areas of erosion



Fig 440. Myelomatosis. Not multiple circumscribed area of decalcification in skull and jaw

were noted in the right ilium and two small areas in the third rib. Still no polyuria, but this appeared later and persisted for 10 months.

A radiation therapy was given and at 3½ years later the skull had been repaired At 12 years of age the skull was completely ossified but the patient was dwarfed.

Gosta Jansson published an account of a boy aged 10 years who had cyst like changes in both femora—the cancellous tissue was destroyed—the cortex thinned An abscess-like shadow surrounded two thoracic vertebræ Typical changes were shown in the skull and clavicle.

pathology based on radiographic evidence of relative opacity of one or more cells is of little value

The frontal sinuses and even some of the ethmoid cells may not be completely aerated until the end of the third year The mastoid antrum may be visualised at 6 months as a small cavity about ¼ inch in size the sinus plate may be visualised by 18 months, but it is during the first four years of life that the mastoid develops its characteristic features. Any inflammatory condition involving the anlage of the air cells may abolish or check their growth—the acellular mastoids of the adult are probably due to inflammatory conditions in the early years of life (see Fig 438,A and B)

The radiographic indications of infection of the sinuses are lack of aeration, dimming thickening of the mucosa, erosion of the cell walls reactive density in the submucosal



FIG. 441B. Lateral radiograph (D W., 22/3 44) showing in the parietal bone multiple circumscribed areas of decalcification which are becoming confluent

bony walls, abnormal expansion of air cells In the well-developed sinus these features can be readily recognised, but in those which are diminutive or irregular the evidence of increased opacity is not so reliable, indeed it may be very misleading if accepted without any clinical evidence of pathology

Pancoast and his colleagues found radiographic evidence of sinus abnormality *in 80 per cent. of a group of* persons examined who showed no clinical evidence of sinus disease

Radiography of the sinuses should not be undertaken during allergic attacks or during the acute stage of colds, for in these conditions general *dimming of the* air cells may be noted. Likewise inflammatory conditions of the soft tissues over the air cells may be associated with some reaction within them which would be indicated by dimming or blurring of the outlines of the cells. Similar reaction may occur in cells in the neigh-

CHAPTER XXI

THE HEAD (*continued*)

Inflammatory Diseases. The inflammatory diseases of the bones of the head and face are due to acute and chronic pyogenic infections syphilis, tuberculosis and the mycoces.

Primary localised pyogenic infections of the bones are most commonly associated with infection of the accessory sinuses and air cells and the teeth. Except in cases of wounds or metastatic foci acute pyogenic infection of the bones of the skull is relatively rare. As with other sites of osteomyelitis there is a latent negative period when localised signs and symptoms may be obvious yet no change is shown on a radiograph (see Fig 441 A) Changes can be shown about fourteen days after onset These take the



FIG. 441 A. Lateral radiograph of skull of D W 12 4 44 with acute osteomyelitis. No radiographic signs of it.

form of multiple circumscribed foci of decalcification over a localised area of a bone These increase in size and many fuse (see Fig 441 B). In the chronic cases the borders of the defects become sclerosed and small sequestra may be recognisable

The Sinuses. Few if any of the accessory nasal sinuses can be radiographically visualised at birth. In isolated cases it may be possible to demonstrate the maxillary antra and even a few ethmoid cells, but generally speaking it can be said that aeration *of all the cells, even those sufficiently developed to show an outline* is incomplete during the first month of life, and in some cases until the third year Consequently opinion as to

Infection is indicated by relative opacity of the particular sinus or sinuses compared with the non-infected sinuses.

Experience is essential in the interpretation of the lesser degrees of *dimming*. The results obtained by radiography are frequently opposed to the findings of transillumination. The latter seldom supplies as much help as the former. It is possible to demonstrate the shadow of a collection *of fluid or of a polypus within* a *sinus on* a radiograph of a patient whose sinuses appear to be normal on transillumination, because in the latter the light is diffused around the foreign object. Distinct from the polypus which is usually associated with a thickened mucosa in an allergic patient, the presence of a mucocele, a feature in chronic sinusitis, may fail to show on the radiograph, because its



Fig. 442. Circumscribed zones of *decalcification of the frontal bones due to osteitis arising* from an infected frontal sinus. Compare with Figs. 439 and 440.

shadow may show little difference from the normal sinus. It may however be indicated by bulging of the walls of the *sinus, which gives them a regular* smooth contour. In other cases it completely destroys the localised area of bone and produces the appearance of a meningocele. Its borders may appear to be more densely outlined.

An interesting example of a mucocele of the sphenoidal sinus is illustrated by *Meisels*[1] in the skull of a girl 13 years of age. This mucocele is indicated by an unusually extensive widening of the sphenoidal sinus and bulging of its walls, the extension being directed backwards and also downwards towards the pharynx.

bourhood of tissues which have been subjected to radium radiation. Comparative radiographs of the two sides should always be made.

It is essential that all antero-posterior and postero-anterior radiographs of the skull for the demonstration of the accessory sinuses are taken with the central X-ray coincident with the plane of a sagittal section and at right angles to the transverse plane of the radiographic film. The slightest obliquity of the head relative to the film may lead to obscurity of the sinuses on one side, and unless this fact is appreciated faulty interpretation will result.

The air cells of the bones of the face and skull present a variability in different individuals which is at least equal to that seen in the whorled lines on the skin at the ends of the fingers. Indeed, it has been seriously suggested that a postero-anterior radiograph of the skull would be a more distinctive record of an individual than the finger prints.

The air cells on the two sides are not symmetrical. On one side they may show great development, on the other little or none. This feature is most noticeable in the frontal sinuses. Radiographs showing air cells on one side only have been misinterpreted, the failure of development being mistaken for obscurity of outline due to a collection of pus.

Radiographs of the sinuses can be taken in the prone or erect position. In the former the fixation of the head is more readily accomplished, but if a small collection of fluid is present it is conceivable that when spread over the anterior wall of the sinus it may not cause any appreciable dimming of the sinus, and if the condition is bilateral, the fluid may be missed.

In the erect position the fluid settles on the floor of the sinus and a shadow of its upper surface, which alters when the head is tilted to either side, can be shown.

This method has many supporters and is the routine method of many radiologists. It is strongly advocated by *Graham Hodgson*, who, in a personal communication, stated that he found fluid levels in 6 per cent. of infected sinuses. This is a higher figure than most workers claim.

The novice in radiography must be warned against the possibility of interpreting *horizontal or oblique shadows of basal structures, such as the petrous portion of the* temporal bone, as fluid levels.

Claus has investigated the radiographic appearance of fluid in the sinuses, and he states that a concave upper surface is indicative of a serous fluid, whereas a convex denotes mucus or mucopurulent fluid, but a similar appearance may be produced by a polypus.

Altering the position of the upper border of the shadow by tilting the head serves to distinguish a fluid line from a superimposed bony line, though one observes that the fluid may be too viscid to show an appreciable alteration in its upper border.

The standard positions adopted for the demonstration of the frontal, ethmoidal, and sphenoidal sinuses and the maxillary antra are illustrated in Figs. 422, 421, 420 and a description of the technique is given on pp. 403–72. These radiographs may be supplemented by others to show further detail of individual sinuses.

The vertico-mental and the oblique projection shown in Figs. 426 and 427 will show individual ethmoid cells unobscured by *anterior middle, posterior and sphenoid* cells.

The sphenoidal sinuses may be shown side by side if a vertico-mental projection is used with the film under the chin with the neck fully extended, or with a small film facing the palate pushed as far back in the mouth as possible, and the central X ray directed parallel with the anterior aspect of the face.

the sinus becomes obscured gradually; so that frequently in the fully developed mastoid the sinus is barely discernible or not at all visible. In acute mastoiditis in the infant, hyperæmia and infiltration of the periosteum overlying the sinus groove tend to obscure the groove, but in acute mastoiditis in the fully developed and in the transitional types, decalcification tends to increase the visibility of the otherwise obscure sinus groove.

Because the zygomatic group is shallow loss of cell outline is more important diagnostically than loss of aeration.

Failure to control the clinical signs and symptoms, is an indication for surgical intervention.

Treatment. Experience proves *that the optimum method of application* in X ray treatment is by repeated small doses at regular intervals until all clinical signs and symptoms disappear The effective dose for each exposure averages 25 roentgens. Following the application of irradiation in several hundred cases of mastoiditis, neither untoward symptoms nor evidence of interference with subsequent growth and development of a young mastoid have been observed.

Contra indications to roentgen therapy are œdema over the mastoid, transient œdema in the region of the emissary vein (Griesinger s sign), torticollis, swelling at or below tip of mastoid, failure to respond, signs of invasion of blood, dura or labyrinth, radiographic evidence of bone destruction, undeveloped mastoid with radiographic evidence of the few cells present, cholesteatoma.

Otitis Media is more common in children than adults. As in other bone infections the radiograph will give no indication in the active stage during the first week, but after this localised decalcification of the bone will appear It may be necessary to make periodic repetitions after an interval of 2 or 3 days such examinations would serve to confirm the early findings and indicate the nature and direction of spread of the infection The decalcification may then be found to be associated with localised absorption or disintegration of bony septa. Similar changes in the cortical bone in contact with the dura may be regarded as strong evidence of epidural abscess. It is considered that inflammatory changes in early life have some influence in checking the cellular development of the temporal bone—certainly the lack of pneumatisation appears to induce towards chronicity of the infection.

Illustrations and details of the radiography are to be found in the monograph by *S Welin*.

The technique devised by *Law Stenvers* or *Granger* may be employed with advantage.

Martin [1] points out that after the age of 6 months a cavity having the shape of the mastoid, can be demonstrated below the tegmen tympani and behind the external auditory meatus. This cavity varies markedly in size, and may measure ½ inch in diameter and show definite cell structure at 9 months, though such *excessive* development is unusual.

Diploetic mastoids are probably diploetic from the start, whereas cellular mastoids begin as large single cavities, which slowly increase in size and usually begin to show cellular structure at 9 to 16 months *He is of the* opinion that pathological changes can be recognised as early as 6 months.

Granger on the other hand, says that the mastoid begins *to* pneumatise after 5 years, and before this time the anterior wall of the lateral sinus cannot be seen through the compact bone *in healthy* mastoids, but with pneumatisation it begins to show He further claims that marked improvement in the inflammatory condition of the mastoids in infants follows X-radiation.

Details of other methods for radiography of the mastoids and illustrations of the radiographs obtained can be seen in the papers by *Richter Worms* and *Bretton*

If the infection has attacked the bony walls of the sinus the radiographs in the acute stage may show blurring of the outlines. When the infection has been present for some weeks sclerosis of the walls may be indicated by an increase in the density and thickness. Osteoporosis or erosion of the neighbouring bone indicates that the bone has been involved by a spreading infection. In the chronic infection of such areas irregular sequestra of a density greater than the surrounding bone may be seen. Similar appearances are to be seen in metastatic pyogenic foci in other parts of the skull.

A series of radiographs, with descriptions of the technique for radiographing the sinuses, are to be found in the well-illustrated papers by *Allen, Chaumet, Hirtz, Hodgson Mayer*[2] *Möhlmann Pfahler*[2] *Waasen* and *Wirth*

Lindblom has described 3 cases in which the radiographs showed a calcareous deposit in the maxillary antrum

Radiographs of the skull after the injection of opaque oils will show the extent and patency of the sinuses. Details of the technique and illustration of the results obtained are to be found in *A W Proetz s* book and in the papers by *Beeler Smith* and *Collins*

Pancoast, Pendergrass and *Schaeffer* make the following comment "Most rhinologists and some roentgenologists have come to feel that the use of opaque media for the diagnosis of intrasinus disease has been grossly abused This is especially true in the case of allergic sinus disease where such substances are not employed without dangerous sequelæ—with good radiographic technique and an experienced roentgenologist it should be rarely necessary to employ opaque substance within the sinuses."

Aerosinusitis (sinus baro-trauma). This is due to the change in the air contents of the sinuses with change in the barometric pressure Trauma is chiefly sustained by increase in pressure as in descent of an aeroplane following low pressure at high altitude If the ostium of a sinus is patent air and in some cases the infective material from the nasal cavity is then sucked into the sinuses. If the ostium is obstructed owing to œdema or other inflammatory changes the negative pressure within the sinuses may become sufficient to cause œdema with transudation of fluid, or submucosal hæmorrhage with or without bleeding into the sinus It is possible by radiography to identify one or more localised submucosal hæmatomata. The other lesions which produce general clouding or opacity cannot be distinguished from pre-existing inflammatory lesions. The hæmatomata usually resolve within a few weeks but organisation of the clot may cause a persistence of the shadow for many months An illustrated account of these lesions has been given by *J A Cocke*

Mastoiditis. *R Schillinger* in a paper on the roentgen aspects of mastoiditis, shows that in fully developed mastoids the cardinal radiographic signs of mastoiditis are (1) clouding or loss of aeration. This sign is produced by hyperæmia, œdema, exudation, granulations, or suppuration. (2) Fuzziness or loss of sharpness of outline of the cell walls. This sign is due to thickening of the muco-periosteum and to decalcification caused by hyperæmia. The liberated calcium is retained in close proximity to the cell wall which is undergoing dissolution and thus produces a shadow which is broader but less dense In this sense, decalcification does not mean destruction. (3) Coalescence or destruction of cell walls. This sign is produced by pressure necrosis resulting in the merger of several cells into one. (4) High visibility of the horizontal semicircular canal which lies in the floor of the antrum. This sign results from decalcification of bone in the periantral triangle which makes that area comparatively translucent. (5) High visibility of the sinus groove in the pneumatised mastoid and diminished visibility of the sinus groove in the infant mastoid In the infant mastoid the sinus is visible because there are no cells overlying its course. With subsequent pneumatisation the course of

hideous mask like appearance, yet, with it all, the mentality may be preserved to late adult life The condition develops insidiously It may become apparent before the aged of 10 years. In one case of the author's a localised prominence of the frontal bone was noticed at the age of 6 years and radiographs showed thickening in the region of the frontal sinus though no air cells could be detected in the thickened bone There were some attacks of headache, but these were not marked until the patient had reached the age of 19 years. The frontal bone in the region of the sinus was then an inch thick, no air cells had developed in it, but the sphenoidal cells and the maxillary antrums were abnormally large for the age. Most of the frontal bone was involved In the proximal parietal bone a large rosette type of diploic vessels was present. There was also a suggestion of early changes in the floor of the middle fossa.

In a girl aged 10 years the floor of the anterior fossa was nearly 1 inch thick, there



Fig 443B Same patient 8/8/46. 18 years after A.

were no frontal air cells, the sphenoidal appeared to have developed to some extent but they seemed to be involved in the bony change which had spread to the base of the middle fossa, the petrous bone and the anterior aspect of the mastoid—some posterior mastoid cells were well developed.

In a man of 80 the walls of the maxillary antrums, the frontal and sphenoidal sinuses and the mandible showed massive thickening and sclerosis. The sella turcica was not deformed, the occipital, parietal and upper part of the frontal bones showed no change (see Fig 443 A). This patient has been periodically examined during the past 18 years. His present condition is shown in Fig 443 B, *i.e.*, 18 years after Fig 443 A. One eye was partly extruded to relieve which partial resection of bone was done The process is

In the natives of the West Coast of Africa there is an osteoplastic periostitis of the region of the nose and antrums which is thought to be a sequel of yaws. It is called by the names of Anakhre, Goundou, Henpue and Henpuys. The face is distorted by prominent painless swellings generally symmetrical, about the nose and antrums they are accompanied by purulent nasal discharge and headache. Radiographs show increased thickness and density of the bones and some expansion of the maxillary antrums.

Inflammatory lesions of the sinuses are said to be the cause of the condition of **Leontiasis Ossea.**

Leontiasis Ossea. *This is the name which has been applied to hyperostosis of the bones of the face and cranium as a result of which the face ultimately becomes hideous —the face of an ogre.* For the development of the bosses of abnormal bone is usually



FIG. 442A. Leontiasis ossea in a man aged 30. Note the density of the bones of the face and base of the skull. Note that the bones of the vault are unaltered.

irregular in extent and distribution. The forehead, the base of the skull, the superior maxilla or the mandible may show asymmetrical development. The soft tissues of the face appear to be stretched over the more prominent parts and the relative position of the eyes may be considerably altered: they become unduly separated, one may be elevated, the other depressed, one or both eyeballs may protrude even to the extent of its complete destruction. The irregular development of the maxilla and mandible may prevent the apposition of the teeth. These features give the face an unchangeable

The condition of hyperparathyroidism may be associated with localised expanded cyst-like areas in the bones of the face and cranium, but the radiographic characters of the other parts of the skeleton would readily decide its nature even if those of the skull were doubtful.

Two interesting examples, one showing the development from youth to late adult life, are given by *G. K. Kirkland.*

Associated with syphilitic osteitis of the cranium one sees marked thickening of



FIG. 444. Polyostotic fibrous dysplasia, see Figs. 182 and 217.

the base and facial bones with obliteration of the sinuses, the appearances of which may suggest leontiasis ossea.

Lawford Knaggs[4] has given a full description with excellent illustrations of the bony changes in this condition. He states that in early cases the nasal fossa may be blocked with bony growth. He classifies the cases into two groups:—

(1) Cases of very chronic periostitis spreading slowly from bone to bone, to which condition the title of "Creeping Periostitis of the Bones of the Face and Skull" can be given.

(2) Cases of diffuse osteitis of the bones of the face and skull in which the changes may be (*a*) general, (*b*) circumscribed, (*c*) local. An example of the latter is illustrated in the massive sclerosis of the jaws following dental sepsis, or irritation.

The radiographic appearance of cases of leontiasis ossea may be compared with similar appearances in the bones of the extremities in some cases of chronic osteomyelitis. They should also be differentiated from the thickenings of the skull due to syphilis, osteitis deformans (Paget), polyostotic fibrous dysplasia, meningioma, polycystic dysplasia.

spreading backward in the frontal bone The condition was first noticed when the patient was 20 years of age—he believes it developed from a blow

A similar but more irregular development of the bones involving the mandible, maxilla and base of the skull was seen in a man of 45.

The sense of sight, smell, taste and hearing may or may not be affected. The condition is slowly progressive, but it may be well into adult life before the more repulsive characters become established

There is no known explanation for the development Some authorities have regarded it as a chronic inflammatory lesion, spreading from the accessory nasal sinuses—this may be thought to have some support from the deformity of the face in the condition of Goundou (see above) which is a bilateral osteoperiostitis of the maxillary region. But though the abnormal bone appears to arise in the neighbourhood of the air cells and obliterate them there is as a rule no sign of suppuration and no sequestrum development. Surgery has been of little effect apart from the relief of pressure symptoms, because the whole of the affected bone cannot be removed, and what remains continues its progressive development.

Burger and *Lehman* have recorded with illustrations a case which was associated with persistent oral sepsis. The dense bone reaction gradually spread and a mature dense bone tumour developed from the mandible. Later its surface became epitheliomatous but a strange disappearance of the dense reaction in maxillæ occurred (see p. 535).

Though there is some suggestion that trauma accelerates the development of the abnormal bone at the site there is no evidence to show that it has any relation to the initial development.

Unfortunately as with many other bone conditions, cases bearing a superficial resemblance to the lesion described have been given the name of Leontiasis ossea and the clinical and radiographic characters of these different lesions have been used to try to establish the nature of the disease in question. Thus some authorities have considered the condition as due to Paget s disease As will be appreciated from the details of the condition on p. 483 the radiographic characters are entirely different. Paget s disease is essentially a disease of adult life—the skull thickening of advanced adult life. It does not show any predilection for the sinuses, which, even in the advanced cases when the facial and basal cranial bones are affected, appear to be distended and not occluded. It does result in a progressive increase in the circumference of the cranium but the face never shows the hideous deformity we see in Leontiasis ossea Whereas in the latter the bones of the face and skull only are affected, in Paget s disease, though often seen in one bone at the onset, in which it may appear to be isolated for a few years, ultimately can be shown to involve multiple bones and frequently the whole skeleton.

There are certain osseous dystrophies affecting the skeleton which are associated *with abnormal development of bone in one or other of its stages of development* In these whether it be in the form of embryonic osteoid, fibrous, cartilaginous or complete osseous tissue we see isolated, though often multiple islands, which are developed sometimes much beyond the normal size of the adjacent bone Such lesions appear to be cystic, often multilocular as polycystic dysplasia fibrou as in the condition now known as polyostotic fibrous dysplasia cartilaginous or osseous as in chondromata and osteomata.

The skull does not escape In some cases it shows localised lesions often very large and disfiguring and these have frequently been interpreted as having the same characters as leontiasis ossea. In the early years of life it may be difficult from the examination of the skull only to tell the nature of the lesion Radiographs of the other lesions, if apparent, or of the whole of the skeleton if not, may be necessary to provide evidence of their nature

to cut down and curette though the general condition of the patient is unfavourable with disastrous consequences The author's former secretary (E. C. S) was known to have an unerupted canine lying in the long axis of the mandible Consequent upon the deleterious influence of the war her constitution was undermined, she developed what appeared to be a septic cyst around the unerupted tooth and thus appeared to call for prompt surgical evacuation. Though she was known to have a tuberculous lesion in one lung apex which had been dormant for some years, the cyst was curetted and within a fortnight she developed the signs of what proved to be a fatal tuberculous meningitis

Tuberculous osteitis of the skull differs from syphilis in that it is more frequently found in young children. The first sign of its presence may be a soft swelling of the scalp —one cause of the so-called Potts Puffy Tumour As in other areas radiographs in the early stages may show no sign of bone changes, but after a varying period, destruction of bone is apparent. Thus in the more resistant patient may appear in the form of multiple sharply punched-out areas of varying size each with a halo of relatively increased density No well-defined sequestra are present but a granular deposit of calcium within the holes may be distinguished when the decalcification of the bone is more marked. Both tables are frequently destroyed and in the larger pulsation may be made out. The overlying skin may necrose and tuberculous pus be discharged; after which, with secondary infection, the skin becomes adherent to the skull and the appearance of chronic pyogenic osteitis may be seen.

In the less resistant patient the infection, which is usually hæmatogenous, invades the diploë producing a large area of decalcification, much of which may later show extensive caries with ill-defined sequestræ of the tuberculous type described elsewhere

All areas of the skull can be affected, but the most characteristic lesions are best seen in the frontal and parietal areas. Infection of the petrous portion of the temporal bone, the ethmoid and the occipital, though probably equally affected, is not so readily detected. The occipital infection is usually due to spread from disease of the upper cervical vertebræ. As the condition is frequently associated with disease of the lungs confirmatory evidence of this should be sought by radiographs Other bones may be affected (see also Xanthomatosis, pp 632–6)

Illustrations will be seen in a very good paper by *D C Straus*

Balestra has published radiographs in a paper which describes tuberculous osteitis in the frontal bone of a child of 18 months. These radiographs show the typical circumscribed holes through the inner and outer plates.

A similar appearance is shown in the radiographs illustrating tuberculous osteitis of the skull and mandible of a boy aged 4 years, described by *Iddison* [1]

Hudela has published radiographs showing destruction of the upper part of the nasal bones and sequestration of the lower part in a case of Lupus Pernio.

Actinomycosis of the bones of the skull may show as multiple small punched-out areas of destruction as in Fig 441 B, or as irregular chronic osteitis with erosion, sclerosis and multiple small sequestra

Coccidioidal Granuloma. *Carter* has published radiographs showing circumscribed areas of erosion of the skull due to coccidial infection. The radiographic appearances are indistinguishable from tuberculosis

Sporotrichosis. Radiographs of the skull and mandible showing multiple, large well-defined areas of osteoporosis which were associated with similar areas of bone destruction in the vertebræ, ribs clavicles and pelvis, were published by *Altschul* [7] in a paper describing the bone changes produced by sporotrichosis in a woman of 62 years of age The radiographic appearances of the mandible in this case suggest a large multilocular cyst

Cranial hemiatrophy with compensatory homolateral hypertrophy of the skull and sinuses and *diminution of the cranial volume as in the case described by A T Ross* should be considered. He points out that in a significant proportion of instances of hemiplegia occurring in early years, radiographs show thickening of the cranial vault, over-pneumatisation of the accessory sinuses and diminution of the cranial volume of the side *corresponding to the brain defect and that an encephalograph shows varying* degrees of atrophy of the brain on that side. Occasionally the vault overlying a pronounced cerebral hemiatrophy is thinner rather than thicker

Asymmetry of the face associated with hypoplasia of the orbit may result from enucleation of the eye in childhood.

Syphilis. Syphilitic lesions of the bones of the face and vault are not so frequent, since the cause of this type of lesion has been recognised and intensive treatment adopted.

Bony lesions may be seen at all ages and in all stages of the disease. In the infant, localised tumefaction of the soft tissues and fragility of the bones may be associated with the radiographic appearance of osteoporosis or erosion of the outer table. Later the appearance of irregular diffuse honeycombing of the outer table, with numerous islands of denser bone indicating sequestra may be shown. Such lesions are more frequent in the frontal bones, but any of the bones of the vault may show similar changes.

Obstruction of the basal foramina may result in syphilitic hydrocephalus.

In the adult no less than four types of change can be recognised :—

(1) Multiple small rounded discrete areas of decalcification with perhaps a suggestion of a denser and somewhat irregular border These have been found in radiographs taken during investigations for headache. They have to be distinguished from secondary carcinomatous metastases, myelomatous and tuberculosis.

(2) Osteoporosis of the outer table which is followed by erosion and subsequent sequestration of multiple islands of bone from the outer table, resulting in marked irregularity of the surface, which in the chronic stage is thickened and sclerosed The base may be much thickened and sclerosed and all the air cells obliterated (see Leontiasis, p 501)

(3) General blurring of the whole of the detail of the skull usually without any sign of localised destruction. *Mental symptoms may accompany this.*

(4) Isolated gummata, most common in the frontal, parietal and temporal bones. They are associated with marked localised thickening of the skull in which sharply defined areas of bone destruction are shown.

The most important diagnostic sign is the response of these lesions to the exhibition of antisyphilitic measures—it is sometimes obtained in the absence of a positive Wassermann reaction and worth doing when the less curable lesions are suspected.

In heredosyphilis radiographs may show erosion and disturbance of growth of the *nasal and maxillary bones, which frequently result in collapse of the bridge of the nose* and perforation of the hard palate.

Schüller has published illustrations of cranial syphilis, and in *Menninger's* paper illustrations of heredosyphilitic cranial osteoporosis are to be found.

As a distinguishing feature between syphilitic and tuberculous osteitis of the skull it has been found that the former is usually a pericranial infection which results in erosions of the outer table whereas in tubercle infection spreads from the diploë more frequently to the inner table

Tuberculosis

The possibility of an inflammatory lesion of bone being tuberculous should always be considered, for localised spectacular radiographic appearances may entice a surgeon

above 2 mm. must be viewed with suspicion Its relation to the median plane can be measured as indicated by *W Fray* who shows that little change is produced by tilting He measures from the internal lamina to the middle of the pineal shadow on both sides or if that is damaged, from the external surface of the skull. If the radiograph is dry the relative positions of the sagittal plane and the pineal shadow can be made by using the technique of *Lorenz*. A line is drawn connecting the tip of both mastoid processes with a compass having one point alternatively at each extremity of this line bisecting curves are made above and below the line The points of bisection are joined It is the relation to this line which shows the position of the pineal shadow

For determination of the antero-posterior shift of the pineal shadow the longest distance from the internal lamina of the frontal bone to the middle of the pineal shadow and the longest distance from the internal lamina of the occipital bone is measured and the displacement can be relatively accurately gauged from the measurement forms of *Vastine* and *Kinney* or *W Fray*

If displacement of the pineal shadow beyond 2 mm. is registered it may be necessary to visualise the lateral ventricles by encephalography or ventriculography for a unilateral space-occupying lesion would tend to push the ventricles to the opposite side as indicated by the pineal shaft. Hæmatoma may be detected during the preliminary steps to ventriculography

In some cases displacement of calcified choroid plexuses may have a localising value

Some authorities have stressed the very useful contribution which can be made by injecting opaque fluids into the cerebral vessels *vid* the internal carotid artery The displacement of the cerebral vessels is very spectacular in some cases and permits of accurate diagnosis and localisation.

Arne Engest who favours prompt radiography for cranial injuries, in a very instructive article, illustrates these diagnostic radiographs. He used 7 to 8 c.c., of 35 per cent. perabrodil. This amount is smaller than used previously by other workers, but he finds that the smaller amount does not cause the pain and movement which is associated with the larger quantities. His injection time was under 2 seconds, the first exposure being made after 2 c.c. have been injected. The method is of use for excluding subdural hæmatoma in cases of cerebral œdema.

C F List and *F J Hodges* have illustrated the value of angiography for demonstrating vascular displacement in the diagnosis of expanding intracranial lesions.

The extent and deformity of fracture of the facial bones may not be appreciated until stereoscopic radiographs are made. Care should be taken not to interpret vessel channels or diploë as fractures.

Serial radiographs of fractures show that the outline of the fractured surfaces are sharp at first, appearing as a clearly defined line if no separation has occurred, but more obvious when a slight gap is found. Gradually the sharp definition is lost, and in the case with no separation, it may not be possible to define its position after 6 months. But if the separation is marked the outline becomes woolly and may even appear to undergo some absorption with widening of the gap The position of such fractures may be apparent for several years after their production. Fractures with but slight separation are gradually bridged, but it may be possible to trace their outlines for several years—usually for a shorter period in children. Depressed fractures in which the fragments are not separated, being more closely opposed, fuse after about 6 months and only the depression, with perhaps some localised sclerosis remains to mark the site.

Stewart Illig Glaser and *Blaine* have contributed valuable contributions to our knowledge on the healing and persistence of fractures of the skull. Fractures of the skull

Bone Changes in Phosphorus Workers. Workers using phosphorus were formerly afflicted with a painful necrosis of the lower jaw usually commencing as a painful abscess at the root of a tooth. In some cases the upper jaw was attacked and the osteitis gradually extended and ultimately led to purulent meningitis and cerebral abscess.

No examples of this disorder occurred in my series

INJURIES TO THE SKULL

Injuries to the skull are becoming increasingly frequent with the increased number of vehicles on the road and they now form a fair proportion of the cases admitted to the casualty departments. Only too often such patients are rushed into radiographic examinations before any adequate clinical examinations have been made or expert opinions obtained and while the patient is suffering from severe shock and unable to co-operate. Consequently the radiographic investigation tends to be wholly inadequate, the radiographs blurred and indefinite and their interpretation, often by the inexperienced casualty officer of little or no value in the treatment of the patient. A negative report given by an expert, even with the aid of the best of radiographs, does not exclude fracture or damage to the brain. Some authorities rightly ignore negative evidence and treat the patient according to the clinical evidence. This is particularly advisable when the radiology or its interpretation is not in expert hands. Consequently it would be wise to postpone any radiographic examination until the patient has recovered from shock and the conditions for radiology improved

As a result of injury to the head the brain may be contused and oedema may ensue. This may or may not be associated with fracture of the skull and such important complications as damage to the middle meningeal artery or other vascular channels and an epidural or sub-dural hæmatoma result, damage to the walls of air cells leading to localised collections of intracranial air within or without the meninges or the ventricular system, damage to certain nervous structures

In many cases these important complications from an injury may occur without producing any definite localising signs, and even with such signs as are present, it may not be possible to determine clinically whether they are due to mere contusion and oedema or whether they are due to lesions on which surgery offers benefit. It must in all cases be realised that the accident which resulted in the injury may have been due to some pre-existing intracranial lesion such as hydrocephalus, hæmatoma, abscess or tumour

Radiographs may show the line of fracture in which case the position respecting vascular channels or other structures should be noted, whether any fragments have been depressed or whether any foreign body is present. Unfortunately in many cases it is not possible to demonstrate a fracture with the standard projections. There may be an indication for special projections to show the internal ear etc., for which the apparatus devised by *Bullitt Chaussé* or *Lysholm* is recommended, and these may reveal fractures not shown on the other projections. Where there is an indication of depression tangential radiographs to the surface at the site of the fracture will indicate the degree of depression.

Whether a fracture is or is not observed, attention should be directed to the neighbourhood of the pineal, for when calcification in it permits of visualisation, it affords valuable evidence as to the presence of any space-occupying lesion. The pineal shadow is occasionally seen in very young children its frequency increases with age so that from 20 years of age and over as many as 50 per cent. of skulls may show the shadow It may be seen on the lateral but not on the A.P or P.A. projections Further radiographs with degrees of tilting of the tube or patient s head may permit of visualisation in such cases. Normally the calcified pineal shadow is in the median plane any displacement from this

thinning of the bone of the area while radiographs taken with the bulge against the film may show very marked digital impressions. In some cases calcium is deposited in the hæmatoma, when its presence will be indicated on the radiograph. If the pineal body is visible it will be displaced to the opposite side In the young patient the skull may show after an interval flattening of the skull at the site of the trauma, some localised calcium deposit in the subdural area and marked bulging of the thinned skull in the occipital and parietal areas.

J Caffey[1] published an account of six infants whose principal affliction was chronic subdural hæmatoma. They exhibited 23 fractures and 4 contusions in the long bones. In no case was there a history of injury and no sign of any skeletal change to which they could be attributed. In a large proportion of infants there was no evidence of injury producing the subdural hæmatomata. The bone changes are not those seen in scurvy but it is reasonable to believe that there was some underlying metabolic disturbance to account for the hæmatomata and the fractures, for the latter have all the characters of those produced by trauma—it may have been overlooked.

Relapsing Juvenile Chronic Subdural Hæmorrhage Under this title *L. M Davidoff* and *C G Dyke* have described and illustrated 4 cases with ages 6, 14 16 and 18 They suggest that subdural hæmorrhage is relatively common. It may go to recovery may calcify or may persist in spite of the disappearance of symptoms because they mould the adjacent malleable skull of the child to accommodate the mass In the last type of case the trauma to the head occurs later in life; bleeding into the sac of the old hæmatoma may again occur with a recurrence of symptoms. Their explanation of the changes are (1) primary increased intracranial pressure by original hæmatoma, exerts pressure on the wall of the anterior and middle fossæ and neighbouring bone, (2) decreased intra cranial pressure, consequent upon absorption from the sac of the hæmatoma, results in hypertrophy of the nasal sinuses and thickening of the cranial vault. They have described similar changes in the skull and sinuses in infantile hemiplegia as a result of cerebral atrophy or hypoplasia.

The following are the changes in the skull which they observed —

(1) Elevation of the sphenoid ridge, superior orbital plate and ridge.

(2) Deepening widening and lengthening of the middle fossa.

(3) Disappearance or indistinctness of the oblique line delineating the postero-lateral wall of the orbit.

(4) Atrophy of the inferior and lateral wall of the superior orbital fissure.

(5) Hypertrophy of the frontal and ethmoidal sinuses.

(6) Thickening of the skull and from encephalographs, (1) normal-sized ventricles (2) slight or moderate displacement of the ventricles to the side opposite to the lesion, (3) relatively slight asymmetry of the lateral ventricle, (4) relatively slight difference in the roof of the lateral ventricles

J Hardman has published a good account of 3 cases of subdural hæmorrhage with radiographs. See also *J W D Bull.*

Effect of Intracranial Tumour on the Vascular Channels of the Skull. In making a complete study of the vascular channels of the skull in normal persons and those with cerebral tumours *K Lindblom* found that these channels afford no reliable localising evidence in glioma of the frontal, parietal, temporal or occipital lobes.

In 30 per cent. mid brain tumours, 31 per cent. pineal tumours, 27 per cent. tumours of the posterior fossa, 8 per cent. in basal ganglia, 4 per cent. in temporal lobe and 2 per cent. in frontal bone, there was a decrease in the vascular markings or widening of the occipital emissary channel Tumour in the posterior part of the temporal lobe may lead to unilateral widening of the foramen ovale.

in infants may be followed by localised dissolution of the bone producing an appearance suggesting a hole in the skull. Damage to the skull of the infant during birth or by faulty posture on an irregular surface may lead to deformity of the skull. The possibiltiy of hemiatrophy should also be considered (see p. 502).

When the fracture involves the frontal, ethmoidal or sphenoidal sinuses or mastoid cells, air may penetrate between the meninges, where it may remain and appear on the radiograph as a localised collection. It may spread out unilaterally in the brain, in the sub-dural space or bilaterally in the sub-arachnoid space, over the convolutions and produce the typical appearance of an encephalogram, or it may lead to distension of the ventricles in which case the radiograph shows a gaseous distension of the ventricles as in ventriculography But it must be remembered that this development takes place subsequent to the injury It may not be recognisable for a week or a month after the injury and unless repeat radiographs are taken after such intervals the condition may be missed. It has been seen after a period of 1–2 years.

An extra-dural collection of air may not be detected because of the density of the radiograph of the soft tissues unless it is suspected and searched for Such collections may be seen to increase on coughing or sneezing and to be controlled by pressure Interstitial emphysema of the face and head may also follow fracture into air cells. The sub-aponeurotic pneumatocele or hæmatoma may be responsible for the development of a skull cyst. The hæmatoma may be completely absorbed within a few weeks but aspiration may be necessary for calcification and ossification may result in the production of a lesion resembling a flat osteoma.

Worms and *Didiee* have published radiographs showing a large pneumatocele over the frontal area. The patient was a jockey aged 25 who had fractured his frontal bone.

In a paper by *Brun* and *Jaubert de Beaujeu* there is a radiograph showing air in the ventricles and subarachnoid space. The patient was a man of 20 years of age who had been shot in the head 3 years before

The radiographs of a man aged 27 published by *Janssen*,[1] show air in the anterior horns of the lateral ventricles which are considerably dilated thereby The fracture of the base of the skull produced a split in the lamina cribosa, through which communication was established with the ethmoid cells. In addition, the very severe contusions had resulted in softening of the brain substance, which permitted air to pass through a fistulous passage from the crack in the lamina cribosa to the lateral ventricle.

The possibility of gas in association with anaerobic infection of the scalp or cerebral tissues following abrasion or fracture should be remembered

A collection of gas within the skull of a fœtus *in utero* in association with anaerobic infection is described and illustrated by *Kemp and Stalworthy* There was no evidence of the cause of the infection.

A most unusual appearance of the skull is shown in the radiograph of a case of "Golden Hair" published by *Knutsson*.[1] This radiograph shows innumerable metallic dots over the area of the scalp, representing fine gold wire, which had been pushed into the scalp holding tufts of hair Two thousand tufts in all were inserted at the cost of 1 000 Swedish crowns. All the tufts broke away within a few months, the gold wire being left *in situ*

Subdural Hæmorrhage. Radiographs taken soon after the injury may or may not show a fissure of the skull or other abnormality After an interval of 2 months some thinning of the bone over the hæmatoma may be indicated by radiography During the next month if the collection is large the thinned bone may be apparent as a localised bulge and later if the area involved is large asymmetry of the skull may attract attention Radiographs taken with the central ray as a tangent to the bulge will show definite

Calcification in the Choroid Plexus. Calcification in the choroid plexus is usually bilateral, but may be unilateral. On the postero-anterior radiograph taken in the nose-forehead position it is denoted by shadows, irregular in outline, lying about 1 inch equidistant from the mid line, on the same plane as the calcified pineal gland. On the lateral radiograph the shadows of the calcified choroid plexuses lie on the same plane as the pineal gland but about ½ inch posterior (see Fig. 42*).

In some cases the outline of the calcification suggests that the calcium is in the walls of tortuous vessels. Asymmetrical displacement of these shadows may be of value in the diagnosis of intracranial lesions.

In the cases investigated by *Dyke* 5·1 per cent. showed calcification in the choroid plexus.

Calcification of the Falx Cerebri. The commonest appearance of calcification of the falx on the postero-anterior radiograph is a shadow the shape and size of a waistcoat button-hole in the middle line of the frontal region. More extensive calcification is seen less frequently; sometimes the whole falx may show evidence of calcification.

It is frequently found by chance on the radiograph of the skull taken to determine the condition of the sinuses and is so often present in association with an infected sinus that the latter may have some bearing on its etiology.

Dyke found calcification of the falx in 6·0 per cent. of the cases which he investigated.

Localised calcification of the dura over the sella turcica and over the dorsum sellæ is also shown.

Dyke reported such calcification to be present in 2·3 per cent. of his cases. Large plaques of calcification may be seen in the dura overlying the cerebral hemispheres and granular deposits of calcium have been seen in the Pacchionian bodies. Similar deposits of calcium have been reported in the tentorium cerebelli. Calcification of the dura has been recorded in cases of head injuries. Extensive calcification of the dura has been seen by the author in Paget's disease of the skull.

Radiographs illustrating the appearance of localised calcification of the falx (the so-called osteoma of the falx cerebri), the dura in the neighbourhood of the sella turcica and over the hemispheres are to be found in papers by *Camp*,[3] *Dyke*, *Löw-Beer*,[4] *Nicotra*[1] and *Schüller*.



FIG. 446. Tracing of radiograph showing calcification in the wall of a carotid aneurysm (L.).

Calcification in the walls of the ventricles is rarely reported as a radiographic finding. *Taft* has published a radiograph which shows a deposit of calcium the shape and size of the lateral ventricle. The patient was a girl aged 12 years and 11 months who suffered from attacks of epilepsy. Some improvement followed the administration of mercury and potassium iodide.

Calcification of the Vessels. Evidence of calcification of the walls of the internal carotid artery may be seen as tubular structures on postero-anterior radiographs of the skull within the boundaries of the orbits, and on the lateral radiograph on a plane with the sella turcica. Similar granular deposits of calcium may be shown behind the dorsum sellæ on the lateral radiograph. These represent calcification of the basilar artery.

A number of radiographs have been published showing calcification in the walls of carotid aneurysms (see Fig. 445).

In the paper published by *Albl* radiographs of the skull of a man aged 62 show two ringlike shadows against the posterior surface of the floor of the anterior fossa which appears to be eroded. The sella turcica is not well defined, but it is reported as being widened. The diploë of the skull are dilated.

With meningioma of the anterior third of the superior sagittal sinus the channels were locally widened and tortuous in association with widening of the foramen spinosum. Eighty three per cent. gave positive localising signs of this nature. The sign was less frequent in meningiomata in the middle third and only about half of those in the posterior third were so indicated. Definite radiographic vascular localisation was given in 90 per cent. of the meningiomata of the cerebralta convexities.

In 00 per cent. of the meningiomata of the lesser wing of the sphenoid hyperostosis was present but only in 20 per cent. were vascular changes apparent.

No localising signs were obtained in meningiomata of the floor of the middle and posterior cranial fossa, region of crista galli or olfactory groove pituitary adenoma; hypophyseal duct tumour; tuberculoma or neurinoma.

INTRACRANIAL CALCIFICATIONS

Shadows of intracranial calcifications are not infrequent on the radiographs of the skull. Such calcium deposits occur in the pineal gland, the choroid plexus, the falx cerebri tentorum cerebelli the dura mater over the cerebral hemispheres the walls of the ventricles the carotid artery the walls of aneurysms and cysts old hæmatomata, old abscesses tuberculous foci tuberose sclerosis, hæmangiomata and such tumours as Psammomata Neurofibromata, Endotheliomata and Gliomata.

Calcification of the pineal body can be recognised on the postero-anterior radiograph in the nose-forehead position as a shadow of variable size (3 to 10 millimetres) in the mid line, about 1 inch above the shadows of the upper border of the base of the skull. It may appear as an irregular amorphous deposit of calcium or as a group of small granular opacities with ill-defined outlines, the whole group together being less than the size of a pea (see Fig 422).

In other cases the calcium deposit is more uniform and produces a well-defined crescentic shadow Variation in its position to the extent of 2 mm. are within the normal. Measurement should be made along the maximum diameter of the skull (see page 505)

On the lateral radiograph it produces an irregular opacity situated about 1 inch above the upper and posterior border of the shadow of the petrous portion of the temporal bone. The value of observing the position of this shadow lies in the fact that it is displaced away from the side of the skull in which a hæmorrhage has occurred or a tumour has grown It was a shift in the position of the pineal shadow which gave *Lasle* the suspicion of a cerebral tumour a diagnosis which was supported by ventriculography and confirmed at operation.

In 3 000 radiographs of the skull, *Dyke* reported a pineal shadow in 51 per cent. He found the shadow displaced from the normal position in 59 per cent. of 404 cases in which intracranial tumours were demonstrated.

Camp[1] found it in 60 per cent. of the radiographs of the skulls of patients over 20 years of age the percentage of positive findings increasing with age. He also found it as early as the tenth year

Lastine and *Kinney* using the method suggested by *Schuller* have charted the position of the pineal shadow by taking measurements from the most anterior point of the inner table of the frontal bone, the most posterior point of the inner table of the occipital bone the highest point of the inner table of the vault, and the level of the base of the skull. They found that the pineal shadow was displaced in 31 per cent. of gliomata and 37 per cent. of meningiomata. A further study of pineal orientation has been reported by W H *Fray* who describes a pineal localiser which permits of early and rapid localisation during routine examination of skulls.

cysticerci. In some cases the calcium deposits appear in the form of small curvilinear streaks. They have been seen as early as 7 weeks after birth and have been noted to increase in size and number while under observation for 2 years The ventricles may be enlarged These changes in the brain may be associated with patchy opacities of consolidation in the lungs in which some calcification may be shown. Osteoporosis of the diaphyseal extremity may also be present. The features of the condition have been well described and illustrated by *C G Dyke A Wolf D Cowen, B H Paige* and *J Caffey*

Calcification in Angiomata. No intracranial lesions present a more characteristic radiographic appearance than angiomata. Calcification within the walls of the dilated and tortuous vessels appears to occur at a relatively early age The outlines of the tortuous vessels are to be clearly seen on the radiographs. In some cases these characteristic shadows may be seen running across the skull from the frontal to the occipital boundaries In a patient with an extensive Hæmangiomatous Nævus of the face the author demonstrated marked thickening of the frontal bones and calcification in the walls of the internal carotid artery

Krabbe and *Wissing* have described 4 cases in which the radiographs showed calcified angiomata. Three of the four patients presented angiomatous nævi of the face.

In a note on the association of extensive hæmangiomatous nævus of the skin (especially of the face) with cerebral (meningeal) hæmangioma, *Parkes Weber* [1] publishes radiographs showing calcification in the walls of dilated tortuous vessels which appear to extend to the limits of the inner tables Contra lateral hemiplegia was present in this case.

Calcification in the Walls of Cysts. A large proportion of the cranio-pharyngeal or Rathke's Pouch Tumours shows calcification in the walls of the supra-sellar cysts (see Fig 448, B) Radiographs show a marked variation in the amount and distribution of calcium deposited. In some cases isolated thin plaques of calcified tissue are shown which give no idea of the size of the tumour There may be widening of the sella and, in some cases, evidence of erosion of the dorsum sellæ or anterior clinoid processes.

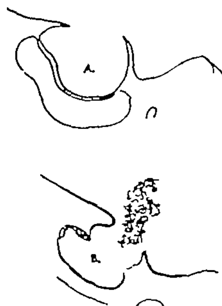


FIG. 448.

A. Expansion of sella and thinning of its wall due to intrasellar tumour

B. Erosion of the floor of the sella, amorphous deposits of calcium above, erosion of the posterior clinoid process and dorsum sellæ. *Rathke's* pouch tumour

These tumours sometimes grow to a large size, and in these cases the radiographs of the skull show some of the signs of increased intracranial pressure, *i.e.*, opening of the sutures, marked digital impressions, dilatation of the venous channels and diploë of the skull.

Such tumours may be present in patients who fail to develop mature sexual characters and in whom delay in fusion of epiphyses persists in the adult.

Of the 253 tumours found in and around the sella by *McKenzi and Sosman* 18·2 per cent. were classified as craniopharyngeal tumours, and in these calcification was detected in 71 per cent.

Calcification in the walls of the cysts of Cysticercus Cellulosæ is a rare radiographic

He states that aneurysm of the internal carotid is less common than aneurysm of the basilar artery

Of the cases of aneurysm of the cerebral vessels investigated by *Cushing* only 25 per cent. showed evidence of calcification.

The recently improved technique of injecting the carotid artery or the ventricles with opaque fluids such as Abrodil or Thorotrast, promises to provide further help in the radiographic diagnosis of intracranial aneurysms and tumours. Thorotrast may be picked up by the ependyma and retained for several years—it outlines the ventricular system on radiographs.

This retention of thorotrast by cells can be utilised for demonstrating the shrinkage of a cerebral abscess. When injected into the evacuated abscess cavity the lining cells take up and retain thorotrast. The contraction of the cavity can therefore be watched by serial radiography and when it has been occluded can be excised.

Calcification in Hæmatomata and Old Abscesses. *Levin* has recorded 2 cases in which calcification was seen in a hæmatoma. In one case, an Indian aged 21 the radiograph shows an irregular calcified mass just behind the sella turcica. The calcified mass was removed from the temporo-sphenoidal lobe and its microscopic characters suggested a calcified hæmatoma. Complete recovery from the headaches previously suffered followed its removal.

The other case was a woman of 29 who gave a history of an old injury to the skull. In this case a rounded calcified mass, the size of a glass marble, was shown in the motor area.

Calcification in Tuberculous Foci in the Brain. Only in a small percentage of cases can calcification be detected in tuberculous lesions of the brain. Two cases have been seen in which multiple nodules of calcium in the brain were shown on the radiograph. In one of these the post mortem examination did not yield any evidence as to their origin, but it is to be presumed that they were of an inflammatory nature.

Tuberculomata are often multiple and being commonly near to the cortex are often associated with fits. They have been found in ages from the first to sixth decade. There is often evidence of disease elsewhere. A radiograph of the chest may supply valuable evidence.

Tuberose Sclerosis. *Bourneville* has described multiple cerebral sclerosis to which he gave this name because of the potato-like appearance of the lesions. These lesions sometimes calcify and produce radiographic appearances which may be mistaken for tuberculomata. The condition is associated with the syndrome mental deficiency epilepsy adenoma sebaceum. This may be associated with thickening of the skull. *M Critchley* described a feeble-minded child of 7½ years who had had attacks of twitching since he was 3 During the last 6 months the child had severe headache, vomiting, twitching and periods of unconsciousness A facial rash showed the characteristic "butterfly" distribution of adenoma sebaceum. White nodules were found in both kidneys at post-mortem—these varied from the size of millet seed to that of a pea. There was internal hydrocephalus and dense islands of sclerosis in the cerebrum from almond to walnut in size, irregularly distributed.

A good account of the condition has been given by *Critchley* and *Earl*.

Toxoplasmic Encephalomyelitis. Toxoplasma is a protozoal parasite (*Rickettsia*) possibly spread by the tick. Miliary granulomata composed of epithelial cells without necrosis or giant cells, are scattered throughout the central nervous system and are a characteristic feature of the disease Later focal inflammation necrosis and calcification occur The latter permits of radiographic demonstration. Such lesions appear on radiographs as multiple small miliary deposits of calcium which might be mistaken for calcified

(3) Marked digital impressions of the inner table
(4) Dilatation of the diploic and surface venous channels.
(5) Deepened Pacchionian depressions
(6) Bulging of the skull, local or general.
(7) Changes in the shape and size of the sella turcica.
(8) Changes in the shape and size of the optic foramen.
(9) Hydrocephalus.
(10) Erosion of bone
(11) Hyperostosis.

One or more of these signs may be present in any given case. The increased intracranial pressure may be due to premature fusion of the sutures or blocking of the ventricular system. The latter is more dependent upon the site than the size or pathology of the tumour Consequently these radiographic appearances may fail to indicate the size or malignancy of the tumour Further it can be stated that the more rapidly the tumour produces increased pressure or invades the brain the less the radiographic signs. Radiography affords most help therefore in those cases in which the increased pressure is due to a slowly growing tumour



Fig 417 Radiograph showing diastasis of sutures of M.S. aged 9½ years. Had epileptiform attacks since age of 3 years and gradual mental deterioration: astrocytoma found.

Diastasis of the Sutures is a most valuable sign of increased intracranial pressure in the young person and one which is clearly indicated on the radiograph by a separation

finding in the skull. Even when the calcified cysticercus can be demonstrated in the muscles, no such changes can be demonstrated within the skull. The eye is a common site for this parasite but it should be realised that the lens when calcified has a similar radiographic appearance this has been illustrated by the author [39] (Multiple Calcified Miliary Granuloma in Toxoplasmic Encephalomyelitis, simulate Calcified Cysticerci). The author [43] also illustrated a case in which the radiographs showed calcification of the intracranial cysts.

Sebaceous Cysts of Scalp. A man aged 37 was referred to the author because he had three large swellings on his head—one as large as a tennis ball. He said he had had them since he was aged 3 years. On the radiographs they appeared to be growing into the cranium, largely obscuring the detail of the bone. Closer examination with a strong light showed they were in the scalp. No bone erosion had occurred.

Dermoids. Radiographs may indicate the presence of these tumours by partial calcification of the walls or contents and in some cases fully developed teeth may be shown as in Fig. 833B.

A remarkable radiograph was published by Scott [1] which showed a large collection of denticles in the suprasellar area of a boy aged 2½ years.

Cholesteatoma. *These tumours usually consist of a collection of waxy or scaly material enclosed in a wall of stratified squamous cells.* These contents are of less density than the brain, consequently the tumour appears on the radiograph as a well-defined radiotranslucent area within the skull and may be mistaken for a localised collection of air (pneumatocele), but it may be distinguished from the latter in that the cholesteatoma often has a dense pencil-lined boundary. It may cause localised absorption of the bone with which it is in contact. The surrounding bone may be sclerosed.

In the case described by *Wertheimer* the patient, a man of 38 had bilateral optic atrophy. His radiographs show a well-defined area of radiotranslucency about the size of a duck's egg on the lateral aspect of the roof of the orbit. It has a thin but dense well-defined pencil-line border.

Kay and *Pack* have described a similar tumour in a man of 27 which, they state, originated from the pia mater at the cerebello-pontine angle.

F. H. Kemp has demonstrated erosion of the petrous ridge by cholesteatoma.

MacMillan considers that any increase of the mastoid antrum over 6 mm. width and 10 mm. depth measured from radiographs taken in the *Law* position is suspicious of cholesteatoma.

S. Welin [2] has written an account of the radiographic evidence of cholesteatoma in the temporal bone. In his series these lesions were found most frequently in those cases with few or no air cells. But they do occur in association with extensive pneumatisation. The lesions must have reached a certain size before it can be detected radiographically, *i.e.*, an apparently normal temporal bone does not exclude cholesteatoma. Twenty of the 114 cases he described gave no radiographic signs.

Gliomata. A small percentage of gliomata contain sufficient calcium to enable the radiologist to localise the site of the tumour. The calcium appears as an ill-defined flocculent deposit (see pp. 507–8, indication of vascular channels).

Sosman [1] found calcification in 11 per cent. of the gliomata which he investigated, but only 5 per cent. showed calcium in the cases investigated at the Mayo Clinic.

CHANGES IN THE SKULL IN INTRACRANIAL TUMOURS

The radiographic signs of increased intracranial pressure are :—

(1) Widening or diastasis of the sutures.

(2) Thinning of the skull, which may be localised or generalised.

my suspicions of an intracranial tumour on the bulged side. At this time the patient presented no other localising signs, and he was reported to have no optic neuritis. In the course of a few weeks further ophthalmic examinations revealed that optic neuritis was developing, consequently a ventriculography was performed. This showed that the left ventricle was pushed over to the right but the right ventricle had failed to fill with air which confirmed the previous interpretation. A flap of bone was turned back at the site of the swelling and the edge of a vascular malignant tumour of the brain exposed.

In some cases localised thinning of the bone may occur on the side opposite to that in which the tumour is growing, due to the tumour blocking the ventricular system of the opposite side.

Schüller has described such cases.

Localised thinning and bulging of the skull is also seen in cases of Astrocytoma and in certain osseous dystrophies, such as Osteogenesis Imperfecta (see Subdural hæmatoma, pp 500–7).

Marked Digital Impressions. These are indicated as shallow scallopings of the inner tables, of the size which may be found by digital impression of a plastic substance, such as putty.

Schüller has stressed the diagnostic importance of accentuated digital impressions. He says that they are always to be regarded as a sign of disproportion between the brain and the capacity of the cranium, even though symptoms do not exist at the time of the examination or did not exist previously. Symptoms of disproportion do not usually appear until they are brought about by such causes as acute fevers, mental or physical exertion or cranial injuries. Under these circumstances, he states, sudden death frequently occurs, the cause of which, at autopsy can be assigned to no other anatomical change except those accentuated digital impressions. He says that these impressions are frequently found in cases of idiopathic migraine.

They are best seen in the young skull and are most marked in the oxycephalic type of craniostenosis and ependymitis (see Fig 430).

Dilatation of the Diploë and inner surface venous channels is frequently seen as a result of increased intracranial pressure but may be present without. The dilatation may be of a greater degree on the side of the tumour. The indentations of the inner table containing the Pacchionian bodies may be considerably deepened and widened on the side of the tumour (see Vascular channels, p 507).

The small irregular areas of osteoporosis not infrequently seen in the frontal bones are probably due to small hæmangiomata.

Changes in the shape and size of the Sella Turcica are commonly associated with intracranial tumours.

Heublein using the technique of *Pendergrass* and *Korablum*, measured the pituitary fossa in 100 apparently normal patients. He found the average antero-posterior diameter to be 10·60 mm. and the average depth 8.30 mm. The largest 18 × 9 mm., the smallest 8 × 5 mm., 7 per cent showed bridging of the sella. In 53 per cent. the contour was oval 28 per cent. round, 19 per cent oblong or flat. Considerable variations were found in the conformation of the walls of the sella, the degree of pneumatisation and the adjacent vascular markings. The latter may be mistaken for fractures. The importance is stressed of the following *statement:* "*The visual fields must be regularly* and carefully checked during and following irradiation and treatment interrupted as soon as noticeable impairment or further damage of the vision is demonstrated. Choked discs are rarely seen with pituitary adenoma; the important finding being a primary optic atrophy.

The changes in the sella due to adenoma, malignant tumours and aneurysm are

of the bones a feature which is particularly noticeable at the sagittal and coronal sutures (see Fig 447) The author has seen it most frequently as the result of metastases from Suprarenal Neuroblastomata. As the age of the patient increases beyond 20 years,



FIG 448. Diastasis of coronal suture. (Secondary neuroblastoma.)

union at the sutures can resist the outward thrust, and the increased pressure causes *thinning and stretching of the bone in the neighbourhood of the suture with resultant bulging*

Thinning of the Skull occurs in cases showing premature fusion of the sutures as well as those in which the increased intracranial pressure is due to obstruction of the ventricular system.

Reference has been made in a previous paragraph to cases of Premature Craniostenosis. Thinning of the skull by increased pressure due to intracranial tumours may be localised or generalised. In the generalised form one area may show a much greater degree of thinning than the rest of the skull and thus may be of great assistance in the localisation of the tumour An instance of this was seen by the author

The patient a man aged 25 complained that he involuntarily dropped articles held in his left hand and suffered from headaches. He was referred to a physician who discovered a slight bulge of the right fronto-temporal area. A small area of the bone underlying this swelling could be pressed in with the thumb and when the pressure was released the bone sprang back *like the side of a ping-pong ball.*

Radiographs of the skull taken in the standard positions showed general thinning of the bone but no other abnormality Radiographs taken with the central X ray at a tangent to the bulged area showed the bone reduced to the thickness of paper whereas radiographs taken over a similar area on the opposite side showed no such thinning On this evidence I reported

in the papers by *Camp*[1] *Dott* and *Bailey* *Erdelyi*[1] *McKenzie* and *Sosman* *Mayer*[1] *Schreiber* and *Schüller*

Erdelyi[1] in his analysis of the findings of 35 cases of hypophyseal tumours, classifies them into three groups

(1) Tumours associated with acromegaly (14 cases) Acromegalic changes, indicated by hyperostoses were present in the bones of the face and the sinuses were all enlarged. The sella was enlarged in length and depth, but the roof aperture was normal in size. The posterior clinoid processes and dorsum sellæ were slightly eroded in some cases, while in others the anterior processes showed similar appearances The sphenoidal sinus was narrowed and flattened The floor of the sella showed evidence of periosteal new bone, probably due to irritation of the tumour

(2) Pituitary tumours without acromegaly (intrasellar 9 extrasellar 7 unclassified, 3) showed destructive changes in the sella—enlargement of the entrance and increase in the longitudinal diameter Destruction of the posterior clinoid processes and dorsum sellæ was evident in all cases, and also in half the cases the anterior clinoid processes showed some erosion. Little or no change occurred in the sphenoidal sinus.

(3) Pituitary tumours with dwarfism (2 intrasellar cases) The radiographic appearances were similar to Group 1

The radiographs of a girl of 17 taken by the author showed a large collection of calcium deposits in and above the sella, the floor of which appeared to have been completely destroyed. This patient had had difficulty in walking all her life For 12 months she had suffered with persistent headache and during the last few weeks complained that she was losing her sight. Her condition had been successively diagnosed as pseudo-hypertrophic muscular dystrophy pituitary infantilism and finally a Rathke s Pouch Tumour

The outline of the sella may be distorted in affected members of the family in Leber s disease (hereditary optic atrophy).

Karlin has investigated the radiographic appearance of the sella in cases of psoriasis. He is of the opinion that radiation directed over the sella may be helpful in treatment, as the sella frequently appears to be enlarged. Osteoporosis, plethoric obesity hyper trichosis and amenorrhœa constitute a syndrome described by Cushing in association with a basophil adenoma of the pituitary gland. *J Craig* has described such a case in a personal communication and gave me the opportunity of inspecting the radiographs.

The Optic Foramen. Enlargement may be due to glioma, neurofibromata, etc. The radiography of the optic foramen will often yield valuable diagnostic evidence, of which no better account can be obtained than that in the paper by *B J Farberov* He gives a careful analytical description of the congenital and acquired deformities due to disease of its periphery or adjacent structures. From this work it will be apparent that know ledge of the normal variants is most essential before attempting to interpret the radiographic appearances. Enlargement of the foramen in pituitary tumour suggests exten sion and poor prognosis from surgery in cases of blindness It can be shown with the projection as in Fig 427

Other cranial foraminæ show enlargement as the result of such lesions as neuro-fibromata.

Hydrocephalus may be indicated in the young patient by general increase in the dimensions of the skull. In the minor degrees particularly in adults it may not be detected until ventriculography or encephalography has been performed. It is usually associated with one or more of the radiographic signs of increased intracranial pressure

Localised Erosion of the Bones of the Skull may be produced by tumours in close proximity to or invading the bone It is a frequent sign in acoustic nerve tumours

described with illustrated case histories. Diotrast was injected into the common carotid artery for the demonstration of aneurysm.

Steiert has investigated the radiographic appearance of the normal sella during its development in 165 children. He tabulates the size of the sella in square millimetres from profile radiographs and gives curves showing the development. These curves show a rapid rise until 4 years of age, after which it remains flat until the child is about 13 when it again rises to a new peak at the age of puberty From the age of 10 years the sella in girls is larger than in boys. Enlargement of the sella in boys begins at 13 years.

Schüller [1] points out that there is no bony wall on either side of the pituitary fossa, so that the pituitary gland can be enlarged without causing any visible enlargement of the sella. He distinguishes three types (1) circular (2) oval, (3) semicircular and states that the shape is dependent upon the size of the sphenoidal sinus. The different types of bridges seen in the region of the sella described as pathological processes, such as inflammation of the meninges or hæmorrhages at the base of the brain, are normal variations of the sella. In the five ligaments—the interclinoid and petroclinoid—bony bridges are often found in children as well as adults

Calcium granules may be present without tumour

Destructive lesions are seen in the walls of the sella. They are often found in the senile. In fact, it is one of the first parts of the skull to show evidence of senile osteoporosis. The carotid artery lying by the side of the dorsum sellæ, pulsates against it and eats into it on both sides The dorsum sellæ is also destroyed by inflammatory processes, osteomyelitis, syphilis, tuberculous or tumour The type of deformity is either a deep or a flat one. Both types can be due to all kinds of intracranial processes, to general intracranial pressure caused by hydrocephalus as well as to localised pressure caused by a pituitary tumour an aneurysm of the carotid artery a tumour of the dura, a cyst or a tumour of the basal nerves. The flat type is found mostly in cases of tumour lying above the sella and the deep type in cases of intrasellar tumour though we find the same type as a rarity in cases of general intracranial pressure.

In cases of intracranial pressure due to premature closure of the sutures the sella is uneroded. Only if the intracranial pressure is due to a hydrocephalus do we find enlargement of the sella. In cases of general pressure the floor of the sella is mostly single In localised tumours two or three outlines of the floor of the sella may be shown, because these localised erosions are often asymmetrical The anterior clinoid processes in cases of generalised pressure are usually thin, but in localised tumours they may be normal or even thicker In localised tumours calcification is often seen in the region of the sella (see Fig 440, B) In acromegaly little or no increase may be seen in the sella in those cases in which growth occurs in the lateral plane or in which the condition arises from hypertrophy of an accessory pituitary *Mayer* [1] has illustrated the changes produced in the sella by various lesions.

Gershon Cohen who analysed the radiographic findings in 65 cases of tumour in and around the sella, states that the first sign of intrasellar growths is increase in the depth of the sella, due to absorption of the floor

The dorsum sellæ and posterior clinoid processes become thin and atrophied Erosion of the posterior clinoid processes is the last change to occur In angle and subtentorial tumours the posterior clinoid processes become atrophied first and the sellar floor last, and in this way the shallow dish-shaped sella, first described by *Schüller* is formed The depth is normal or reduced, but the antero-posterior dimension is increased With adenoma of the pituitary the sella is enlarged in all directions

Radiographs illustrating the changes in the sella due to tumours are illustrated

Moore classifies the hyperostoses into nodular sessile and mixed, also those confined to the squama of the frontal bone the orbital plate or a combination of the two The radiographs show a very wavy outline of the nodular type and a smooth plaque of dense bone in the sessile type. The thickness of the hyperostosis diminishes as it recedes



FIG 449 Intracranial osteophytes growing from the frontal bone.

from the mid line It gradually obliterates the diploë but does not cause any alteration in the external surface of the outer table.

The cavity of the frontal sinus does not appear to be diminished though its posterior wall is thickened.

Moore considers that the use of parathyroid hormone is worth a trial as well as a rachitic diet to counteract excessive calcium deposit. He advocates decompression for Jacksonian attacks and surgical attention to the optic groove if the optic nerve is compressed

When the bones at the base are involved as in Osteitis Deformans Leontiasis Ossea, or Albers-Schönberg's Disease, the basal foramina may be constricted and nerve lesions produced.

In some cases the condition appears to be a familial affection, and in these all the bones of one side or of the whole skull may be involved. *Klippel* and *Feldein* have described cases of familial hyperostosis of the skull.

Hyperostosis may be associated with epilepsy or idiocy Specimens of such skulls in which the bone has reached the thickness of an inch or more are to be seen in the Museum of the Royal College of Surgeons. Localised or general hyperostosis of the skull occurs in some cases of premature craniostenosis, as in the case illustrated by *Schüller*

and of tumours around the sella. It may be the striking feature in radiographs of patients with cholesteatoma, neuro-fibromata, sarcoma and carcinomatous metastases, lipoid and other granulomata, also leukæmia.

Erosion of the dorsum sellæ is seen in some cases of cerebellar tumours.

It is essential to take radiographs in several planes of the area of the skull suggested by clinical signs as the possible site of the tumour. Localised erosion may be missed if only the standard postero-anterior and lateral radiographs are made. In cases of suspected acoustic nerve tumours the radiographs, as in Figs 423 and 423, should always be made.

Towne points out that these tumours arise in the auditory canal, and that there is a long interval, averaging about 5 years between the initial auditory symptoms and the appearance of signs which make the diagnosis certain. These signs consist of palsy of the fifth and seventh nerves, cerebellar ataxia and internal hydrocephalus.

He publishes the radiographs and details of 5 cases in which erosion of the petrous bone on the side of the tumour is shown.

Pancoast has also illustrated a series of cases showing erosion of the petrous bone

Erosion of the walls of the sinuses should always raise suspicion of a malignant tumour

Camp[1] has published radiographs showing localised erosion of the dura due to neuro-fibromata and endothelioma. *Wakeley*[2] has published a radiograph showing erosion of the vault by a meningioma.

Hyperostosis of the Bones of the Face and Skull is seen in many conditions. It may be localised to a part of one or more bones, the whole of one side, or all the bones may be thickened. Such changes we see in polyostotic fibrous dysplasia.

Hyperostosis frontalis interna was the term coined by *Sherwood Moore* in 1935 for a condition which had previously been described by *F. Morel* in 1930. *Morel* refers to previous descriptions of similar cases. *D M Greig* in his monograph on "Intracranial Osteophytes" describes the appearances found by him in the study of 188 crania in the Royal College of Surgeons Museum in Edinburgh.

S Moore has supplied us with many additional facts from his study of 72 living cases. The condition occurs predominantly in the female, 97 2 per cent., and is frequently associated with obesity headaches and progressive mental deterioration, intellectual slowness, depression, anxiety, sleeplessness, migraine and thyroid disturbances with bizarre mental and neurological signs and symptoms which appear to increase in severity with the increase in the thickness of the hyperostoses and presently receding atrophy of the cerebral cortex. There is evidence of disturbance of fat and calcium metabolism in some cases, which the findings of *Morel* suggest might be due to some lesion in the region of the third ventricle.

The author has met with several cases in which radiographs show very pronounced nodular hyperostosis on the frontal bone in patients with no suggestion of obesity. In fact the patients appear to have become progressively thinner with the fading mentality. In one patient, aged 77, the doctor reported that until 8 years ago she was mentally alert but since that time her intelligence has faded and she has become nothing but skin and bone. Radiographs show well-defined nodular hyperostoses (see Fig 440). Another woman, aged 23, who showed a well marked hyperostosis frontalis interna, had had a radical operation on the left mastoid when she was 17 years of age and several operations on the left ethmoid and frontal sinuses in the interval. During the 8 weeks preceding the demonstration of the hyperostosis she had been in bed having a temperature of 103 and a swelling over the area of a well-developed right frontal sinus.

the normal. At operation a cylindrical tumour was found in the region of the optic chiasma. Large areas of the cranial bones were absorbed, including the petrous There was diastasis of the sutures. Asymmetry of the mandible face and orbit were present also atrophy of the facial bones Marked asymmetrical enlargement of the orbit up to double the size of the other orbit. The sella may be markedly enlarged or may be normal though there may be severe destruction in other parts of the skull Defacement and enlargement of foramina occurs. Most of the facial bones on one side may be destroyed.

Congenital distribution was noted in some cases

The radiographs and photographs of a patient with neurofibromatosis were sent to me by *E C Topping* These showed general decalcification with poor compact tissue (none in the bones of the hand) and multiple complete and incomplete fractures, kypho-scoliosis with compression of the vertebral bodies. No cystic changes. The appearances of the bones resemble those in Type B renal rickets, and it was thought by the author that a renal condition was present in addition to the neurofibromatosis, as he has found it in some cases of other dystrophies.

Radiographs of the spine at the site of abnormal curvatures may show widening and erosion of the walls of intervertebral foramina, the vertebral body (which may collapse) and, in some cases, of the transverse process or ribs The intercostal space may be increased and a paravertebral tumour shown. In some cases with general decalcification, as in the case cited above, one or more vertebral bodies may collapse though no localised tumour is present.

Cranial–Chordomas. These occur at all ages

The nature of this tumour in the cranial area is not so readily appreciated as it is in the lumbo-sacral area. It arises from the upper part of the cervical spine or the region of the nasopharynx or sphenoid In the latter from the region of the clivus it usually grows towards or beyond the sella.

The tumour appears to completely consume the bone as it progresses—the surrounding bone gives no indication of any reaction

Not all of these tumours respond readily to X radiation, though this has been claimed as one of the characters of the chordoma (see Fig 330).

Rose[1] has published radiographs of the skulls of negro boys suffering from anæmia which show hyperostosis of the posterior parts of the parietal and the occipital bones somewhat similar to the appearance seen in Cooley's Anæmia

Radiographs of the skeleton of one of the author's patients, a boy aged 4 years with generalised polyostotic fibrous dysplasia showed marked general hyperostosis of the skull which was associated with severe osteoporosis, absence of compact tissue and an appearance suggestive of cartilaginous metaplasia within thin bony casings of all the other bones. The child had suffered from jaundice and bleeding from the cord during the first ten days of life. During the last 8 years the skull has markedly thickened and is now over 1 inch thick (see p. 571)

General hyperostosis occurs in Paget's Disease and Syphilitic Osteitis, while localised deposits are found in association with gummata or as the result of trauma, *chronic* sepsis or osteogenic sarcoma.

It was shown by *Barling* and *Leith* that localised hyperostosis of the skull can be due to an underlying Meningioma. In the first instance the hyperostosis may be merely a hyperplastic reaction of the bone to the pressure of the underlying tumour but later tumour cells may invade the thickened bone resulting in a still more marked reaction. Both tables may show a localised thickening over the site of the meningioma.

Excellent radiographs and photographs showing localised hyperostosis due to a dural Endothelioma have been published by *Kolodny*[2]

The most extensive forms of hyperostoses are seen in cases of **Leontiasis Ossea** as will be seen from Figs. 448 A and B and the illustrations in the paper by *Lawford Knaggs*[4]

In **Albers-Schönberg's Disease** also the bones of the skull may be thickened to a very great degree and this with the high calcium content, leads to the radiographic appearance one might expect to be obtained from a skull cast in plaster Such an appearance was obtained by the author in the radiograph of the skull of a girl aged 17

Hyperostosis may also be present in association with pituitary adenoma as in gigantism. It has been seen by the author in association with extensive **haemangiomatous naevi of the face.** *Hæmangiomata* may be distinguished by the appearance of multiple phleboliths in the soft tissue tumour The bones of the face may be distorted and displaced by the angiomatous growths in the young person.

In **Neurofibromatosis** marked hyperostosis of the whole skull, with enlargement of the sella turcica, and calcium deposits in the region of the lateral ventricles, was seen



FIG 450 Hyperostosis of the skull of a woman aged 20. Note the marked thickening of the skull, the enlargement of the sella and the calcification in the region of the lateral ventricle Multiple neurofibromata.

by the author in a woman of 20, who had had persistent headaches for 6 or 7 years (see Fig 450). Three years after these began she commenced to have epileptic seizures, and during the last 3 years deafness had developed. At the post-mortem examination bilateral tumours the size of hazel nuts were seen involving the auditory nerves Multiple tumours were present on the outer surface of the dura which was adherent to the brain. These superficial tumours lay in beds excavated into the inner table of the skull. Multiple tumours were also found involving the spinal nerve roots *Microscopically the tumours* were of the nature of Neurofibromata.

T Rosendal has also described the cranial changes in 8 cases of neurofibromatosis (von Recklinghausen) Bilateral optic atrophy developed in 6 months in one case in 3 years in another The radiographs showed widening of the foramen to three times

The radiograph (Fig 45?) shows an osteoma of the frontal region which had developed after a similar tumour had been removed several months previously

In the case published by *Armitage* the large osteoma of the frontal sinus was associated with multiple mucoceles, one of which communicated with the ventricle

Cushing has published a radiograph showing a large frontal pneumatocele, which was originally mistaken for a cholesteatoma, in association with a small osteoma. A



FIG 432. Osteoma growing in the floor of the frontal sinus.

small orbito-ethmoidal sinus had developed alongside the osteoma and given rise to the pneumatocele

Reference has been made on page 501 to a case of localised osteitis fibrosa of the skull. Large diffuse osteomata and chondromata have been found unassociated with similar lesions elsewhere in the skeleton.

H J Perlberg and *A L. Kruger* have illustrated and described the case of a male Italian, aged 45 years who complained of weakness in the fingers. He had never had headaches nor cerebral symptoms and had normal mentality He was noticed to have a prominent forehead at the age of 4 years. Present radiographs show a massive dense osteoma involving practically the whole of the frontal bones and in bulk was half the size of the cranial cavity There was also unusual density of the superior maxilla and base of the skull. The tumour protruded from the orbital plates into the orbit on both sides causing exophthalmos.

Angiomata of the soft tissues of the face may produce distortion of the bones They are associated with calcified phleboliths.

Primary Tumours of the Bone. Some interesting examples of benign fibro-osseous tumours of the skull and facial bones are described by *K C Eden* and the monograph on primary tumours of the cranial bones by *E F Geschickter* is recommended for study

Similar cases have been published by *Camp* and *Schüller*

The reader is referred to the articles by *Adson*[1] *Schüller Hickey W F Dandy C W Schwartz, Pancoast, Pendergrass* and *Schaeffer* and *Sosman* for details of



FIG. 451A. Radiograph of skull showing an angioma in the frontal bone This tumour has been slowly growing for several years.



FIG 451B. Tangential radiograph of tumour showing radiating spicules. This type of reaction is seen in some meningiomata, but the inner table is then usually similarly changed.

the technique and findings in ventriculography and encephalography as it is impossible to deal adequately with these diagnostic procedures within the scope of this volume.

Reference has been made elsewhere to the work of Greig on intracranial osteophytes. An example is illustrated in Fig 449

Angioma of Skull. The radiographic appearances of angioma of the skull resemble tumours of this nature growing in other bones—they appear to have a centrum from which radiating fibres are directed (see Figs 451 A and B).

TUMOURS

The commonest tumour of the bones of the face and skull is the ivory osteoma.

This is usually found in the neighbourhood of the frontal or ethmoidal sinus or orbit. The tumour even when discovered by accident, of the size of a pea, is very dense and clearly defined As the tumour grows, it tends to form a rounded mass within the cranium. Recurrence is liable to occur possibly due to the fact that owing to the position a sufficient area of bone is not resected

In a personal communication *Gosta Forssell* informed me that osteomata in this region, associated with enlargement of the sella turcica, he had seen only in Jewesses.

and posterior clinoid, later the sella floor and lastly the tuberculum sellæ and anterior clinoid processes may be seen. Later it may burst into the sphenoidal sinus. Such are the changes seen in the chromophobe adenoma. The mixed type is not easy to recognise. With definite acromegalic changes and a large sella we may suspect the presence of a mixed type of tumour because the chromophile adenoma is not apt to be very large and yet the bony changes clearly indicate the presence of active chromophil cells. The basophil adenoma is relatively uncommon, and as it is usually very small there will rarely be any change in the configuration of the sella turcica; but there will be, if the tumour is active, a very irregular halisteresis of the vault and to a somewhat less extent of the bones of cartilaginous origin; the basic bone structure is unaltered. The halisteresis is of the granular type.

Hæmangioblastoma. *C. G. Dyke* and *L. M. Davidoff* describe the cardinal features for the diagnosis of this tumour. These are: a middle-aged patient with pneumo-encephalographic findings of slight to moderate dilatation of the lateral and third ventricles, moderate enlargement of the aqueduct of Sylvius, rostral bending of the caudal half of the aqueduct of Sylvius, and narrowing of the cisterna pontis. The plain radiographs usually reveal only slight atrophy of the posterior clinoid processes, floor and dorsum of the sella.

Sarcoma. The bone changes seen in other areas of the skeleton may accompany the growth of this tumour in the skull.

A Sarcoma of the mandible in a boy of 7 showed on the radiograph localised erosion of the bone with some calcification in the soft tissues of the tumour. Details are given in the chapter on bone tumours of a case in which the shadow of the normal hyoid bone projected into the shadow of the mandible led to the erroneous diagnosis of sarcoma of the mandible.

Hæmangioma of the mandible has been seen in a number of cases. The possibility of fatal hæmorrhage on operative interference should not be overlooked. In the cranium these tumours produce a rounded area of relative translucency from the middle of which trabeculæ radiate (see Figs. 451 A. and B).

Primary malignant tumours in the accessory sinuses lead to obliteration or erosion of the sinus outline.

Metastases of Endothelial Myeloma, Sarcoma and Carcinoma are not infrequent in the cranium. They produce bone changes similar to those produced by malignant cells in other bones. Multiple Myelomata and Secondary Carcinomata produce multiple small circumscribed areas of rarefaction similar to Figs. 439 and 440. Marked thickening of the skull with depressions in the inner table has been seen in cases of von Recklinghausen's Neurofibromatosis (see Fig. 450).

Winkelbauer and *Lehman* have also illustrated and described changes in the skull due to this cause.

Metastases in the brain occur most frequently in sarcomata. In melanotic sarcomata the proportion giving such metastases is very high; they are more common from bronchial than from breast carcinoma—some authorities give the figures as 30 per cent. and 5 per cent. The primaries in the lung, like those in the prostate, may remain unsuspected until the symptoms of metastases develop. The age of incidence depends on the type of primary. In the young, the neuroblastoma; in adolescence and early adult life, sarcomata; in middle life, the most frequent is bronchial carcinoma, but primary carcinoma in any site may contribute; beyond the age of 60 the number is relatively small and the site of the primary various.

One of the most striking clinical features, as might be expected, is the short history associated with the development of metastases. The severity of the headache which

Tumours of the Acoustic Nerves or Eighth Cranial Nerves C W *Schwartz* records that they form 8–9 per cent of all intracranial new growths they arise from the distal or shorter portion of the nerve—which is similar to a peripheral nerve. The two portions differentiate at the level of the internal acoustic meatus The terms Neurilemmoma, Perineural Fibroblastoma, Neuroma Neurinoma, Schwannoma, have been applied. It is commonest during the third decade in young persons it occurs in association with neurofibromatous and then often is bilateral. The tumour may show malignant characters it grows very slowly—insidious symptoms may extend over 10 years. It may show degeneration but rarely enough calcium to cast a shadow It may grow within the auditory canal out of the auditory meatus and into cerebello-pontine angle. It has been found in the petrous pyramid, the tentorium cerebelli, the cerebellum and the brain stem. Symptoms begin with tinnitus which gradually becomes worse, hearing will be impaired, this may remain stationary for some years The fifth and sixth nerves may be involved later sometimes the seventh also the ninth and tenth are often involved. The patient may show a " cerebellar gait. The tumour produces symptoms which are perhaps the most clearly defined of the brain tumours.

The sigmoid and possibly the petrosal sinuses may be partly occluded Some branches of the basilar artery may be compressed. If large the intracranial pressure is increased and the cerebellar tonsils may be pressed into the foramen magnum.

The tumour can be distinguished because it involves the eighth nerve first and does *not produce rise of intracranial pressure until late.*

He recommends stereoscopic films of both sides of the head films taken in the occipital position. in the semi-lateral (*Stenvers*), nose-chin (*Waters*), and brow-nose with the tube centred between occiput and vertex and tilted caudally 5° in order to cast the shadows of the petrous pyramids behind the orbits

The petrous bones are often asymmetrical. First sign of the tumour is demineralisation of the cortex of canal enlargement of meatus with atrophy of its walls, pressure notch-like defect in petrous ridge, its margins atrophic. Ventriculograph may show distortion of aqueduct and cystic enlargement of the homolateral portion of the cisterna.

There may be homolateral atrophy of the dorsum sellæ. Complete surgical removal constitutes a cure. The tumour is not radiosensitive.

Tumours of the Hypophysis Cerebri. C W *Schwartz* states that these tumours constitute a somewhat variable proportion of all intracranial tumours, depending upon the clinic, but a general average would be about 18 to 20 per cent. Of these about 70 per cent. would be tumours composed almost entirely of chromophobe cells, about 25 per cent. would be predominantly chromophilic, and about 5 per cent. would be classed as definitely mixed or transitional His statement that chromophobe adenoma is usually much larger and gives rise to hyperpituitarism resulting in either gigantism or acromegaly depending on whether or not the epiphyses have closed is questioned by pathologists to-day The basophilic tumour is rare and gives rise to Cushing's syndrome This syndrome can also be caused by tumours of the adrenal glands the ovaries and the thymus. It is uncommon to find a pituitary adenoma in a patient under 15 years of age Tumours in early stages may be difficult to diagnose and may appear to remain dormant as far as growth is concerned. The sella may therefore appear normal but the tumours be able to produce endocrinopathy This may lead to the acromegaloid type of skull, with the rather prominent frontal sinuses developed anteriorly and not at the expense of the cranial capacity and heavy facial bones but no prognathism. The tables of the skull are thin, the diploë large Such appearances are seen in the chromophilic type of adenoma. In the presence of adenoma which is gradually enlarging we see demineralisation of the cortex of the inner portion of the dorsum sellæ

CHAPTER XXII

DENTAL RADIOGRAPHY

The radiographic demonstration of pathological conditions of the maxilla and mandible requires special technique and may necessitate X ray exposures with extra and intra-oral films.

Generally speaking fractures, and other lesions involving a large area of the bone, as well as those cases where the relation of a lesion to the neighbouring structures is of great importance, can best be demonstrated with extra-oral films. These are placed against the side of the lesion and the X ray tube so angulated that the shadow of structures liable to obscure the detail when superimposed on the area under investigation, are projected away. Thus a radiograph of either side of the mandible can be obtained by causing the patient to lie in a prone position with the head turned to the affected side and tilted by placing a sand bag beneath that part of the casette which falls below the plane of the mandible or by the use of a specially constructed angulated casette holder.

The tube is so placed that the central ray passes beneath the uppermost side of the mandible, projecting the shadow of the latter above the plane of that part of the mandible in contact with the casette.

By altering the amount of rotation of the head different segments of the mandible can be so investigated. *Radiographs of the temporo-maxillary joint can be made in* this way but it is advisable to supplement those with radiographs taken with other projections. A projection of this joint, which gives rather less distortion, is obtained when the patient lies with the side of the head on a film, the median sagittal plane being parallel with the film the tube being 80 inches above and on a plane 1 inch above the base line and 1 inch behind the external auditory meatus, the central ray being projected downwards and forwards, the tube being angulated 10° in each direction for this purpose. The relation of the condyle to the articular eminence with the mouth open and shut must be appreciated if errors of interpretation are to be avoided. Arthritic changes in the temporo-mandibular joint may be present on one side only. The joint space may be diminished, the surfaces flattened and irregular and the condyle may fail to ride on to the tuberosity when opening the mouth. The pain of which the patient complains may appear to be on the opposite apparently healthy joint which shows full range of movement of the condyle.

With acute arthritis of the temporo-mandibular joint, the posterior joint space, *i.e., the space between the posterior surface of the condyle and the fossa, may be* increased yet the anterior surface of the condyle may appear to be closer to the condylar eminence while the healthy side (which should always be taken for comparison) shows forward travel on to the eminence, *i.e.*, the movements on the diseased side are restricted. The increase in the posterior joint space and the slight depression and forward position of the condyle suggests effusion into the joint. A good example of temporo-mandibular hydrarthrosis was published by *A. L. Backman* and *A. L. Bershorn.*

Postero-anterior radiographs with the tube centred over the midline on a plane with the joint, or over the joint may also be helpful.

For the maxilla radiographs taken with the film in the occlusal plane and stereoscopic radiographs will be found to give evidence liable to be missed in small dental films or in the plain radiograph.

comes as a relatively acute symptom, appears to be out of all proportion to the degree of intracranial pressure The rapidity of the development is only approached by some gliomata radiographs of the chest, renal area and pelvis may supply evidence useful for differentiation

Ventriculography of the Fourth Ventricle. *Eric Lysholm*[2] prefers hard or flat and well-exposed radiographs, for in such the margins of the smaller collections of air such as those in the aqueduct and fourth ventricles are fairly uniform and if the normal picture is memorised very small lesions will be more readily detected. To ensure successful examination a sufficient quantity of air approximately half the volume of the lateral ventricles must be introduced. In practice the air column as seen in the lateral view taken with the central ray parallel with the floor should reach a height of at least 3 or 4 cm. Filling of the fourth ventricle with air requires special manœuvres. The patient is first placed on his left side so that the greater part of the air collects in the anterior horn of the right ventricle The head is then rotated to allow the air to pass through the foramen of Munro into the third ventricle. This is accomplished by mild shaking of the head. Rotation is continued until the forehead rests against the examining table. Three exposures are made in rapid succession, the patient's position remaining unchanged The first view is in the frontal projection with the tube set at 90 to the film the second a semi-axial view with the tube angled 30 towards the feet the third, a lateral view with the ray parallel to the floor These exposures completed, the rotation of the head is continued, thus enabling the air to collect in the left ventricle The head is then rotated in the opposite direction until the right side is uppermost: the main part of the air collects in the lateral ventricle but some passes through the foramen of Munro to the fourth ventricle the radiograph is then taken. The head is now slightly lowered and turned so that the left side is uppermost, and another lateral radiograph is taken. If the mastoid processes are large and aerated, an oblique film is made in order to free the shadow of the fourth ventricle from that of the mastoid cells. The films are then developed and studied If the fourth ventricle fails to show properly the procedure is repeated. In order to release an air lock the patient's head is lowered and rotated to the position shown in Fig 453 C and then shaken. In this position the fastigium is uppermost

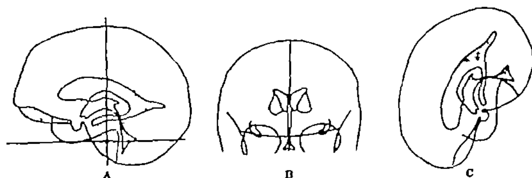


Fig. 453. Reconstruction of the normal ventriculogram from radiographs. A, Lateral view B Antero-posterior view (*Lysholm*)

C Position of the patient's head used to facilitat free flow of fluid and air out of and into the ventricular system. (*Lysholm*)

The classical monographs on benign tumours in the lateral ventricles and the third ventricle by *W E. Dandy* are recommended for study

the roots of adjoining teeth The more acute the inflammation the less defined the periphery of the lesion. In the more chronic cases, radiographs show separation of the lamina dura from intimate contact with the affected tooth over a localised area due to proliferation of inflammatory cells beneath the periodontal membrane Also absorption of the adjacent alveolus, but reaction in the latter is registered by an increase in the density of the bony walls of the lesion as in Fig 458

Four types of change may be found in these tissues in association with sepsis and toxic absorption.

(1) The acute, in which the radiographic changes are little or nil, but the clinical signs and symptoms are prominent.

(2) The subacute in which the lamina dura and adjacent alveolus are decalcified but the boundaries of the lesion are ill-defined.

This lesion also produces localised clinical signs and symptoms (see Fig 457)

(3) The chronic, in which the lamina dura is stripped from a portion of the root and a cyst like cavity surrounds the apex or abuts against the root. The lamina dura may appear to be detached from the root and to blend with the sclerosed wall of the cyst-like structure, but in some cases the lamina dura at the site of the lesion is completely decalcified and there is no suggestion of sclerosis of the bony wall of the cyst.

The presence or absence of this sclerosis is probably due to the nature of the infecting organism and the local resistance to its activity (see Fig 458)

(4) The toxic, in which the essential change is thickening of the cementum and sclerosis of the adjacent alveolar bones. The lamina dura, if it can be distinguished, is thicker than normal.

This type of lesion is usually associated with dead teeth from which absorption of toxins is taking place (see Figs. 459 and 460).

It is most important that the lesions of the types 3 and 4 be recognised from the radiograph as they are seldom associated with any localised clinical signs, yet frequently are the site from which toxins are being absorbed Most clinicians are familiar with cases showing grave symptoms of toxic absorption which have recovered following the radiographic discovery and subsequent extraction of such teeth. *Leonard Mackay* has published a very instructive account of the importance of these lesions.

There are certain normal structures which sometimes produce radiographic appearances resembling pathological lesions, and grave consequences have resulted when the latter have been missed by the mistake of interpreting pathological lesions as normal structures. A less serious mistake is made when the normal structure is mistaken for a pathological lesion, as this, at most, leads to the sacrifice of a healthy tooth. More than once has the shadow of the coronoid process been mistaken for a retained wisdom root and attempts made to remove it. It is therefore most important that the student of radiology has a sound knowledge of the anatomy of the part with its variations and the radiographic appearances of these normal structures. The erroneous impressions created by a poor clinical examination are not minimised but often accentuated by a supplementary X-ray examination of a like nature and while it is unwise to put aside opinions formed from a sound clinical examination because of doubtful X ray appearances, it is equally unwise to ignore the radiologist's opinion on characteristic radiographic appearances, because of doubtful clinical signs. The author has been astounded at the errors in the interpretation of radiographs of normal structures in this area by men who must have been well versed in the anatomy of the part. For instance in the radiographs of the mandible taken with the technique described in the first part of the chapter the shadow of the hyoid bone will be seen in some cases projected over the angle of the mandible This was interpreted as evidence of a sarcoma and

In addition radiographs taken to show the detail of the maxillary antrum as indicated on pp 466–71 may be very desirable in certain cases.

Though the pathology of the jaw bones is similar in many respects to that of other parts of the skeleton the specialised structures concerned with the development of the teeth are liable to undergo specific changes which produce characteristic radiographic appearances. Attention will be given to these conditions only Notes on general bone pathology will be found by the student in other chapters from the index.

The essential features depicted on the radiograph of a tooth are outlined in Fig 434

Any irregularity of these outlines is usually associated with pathology consequently in examining the radiograph the observer must satisfy himself either that these outlines are all normal or account for any irregularity which may be apparent.

The enamel, dentine, and cementum are relatively opaque when compared with the surrounding structures the central part of the tooth, the pulp chamber and root canal show because they are of less density

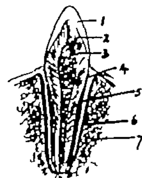


Fig 434 Diagram showing the chief structures of a tooth which are indicated on a radiograph.
(1) Enamel
(2) Dentine
(3) Pulp chamber
(4) Periodontal membrane (Dental periosteum).
(5) Cementum.
(6) Lamina dura
(7) Alveolar bone.

Localised areas of diminished density extending into the tooth from the surface of the crown or denuded root of a tooth generally represent foci of caries. While these are usually most apparent on clinical examination, if they occur beneath approximated fillings or on a surface packed against the neighbouring tooth their presence may be revealed by radiography only

As such lesions frequently give rise to much discomfort and pain, the cause for which cannot be established on clinical examination, search must be made on the radiograph for indications of them, particularly in the sites above indicated.

The relative transparency of the pulp chamber and root canal may be diminished by the production of pulp stones or secondary dentine.

Pulp stones appear on the radiograph as rounded or ovoid opacities within the central cavity of the tooth, whereas the secondary dentine reduces the calibre of the nerve canal, an appearance which is more frequently seen in the teeth of elderly patients (see Fig 435)

The cementum increases in thickness as the result of chronic irritation and may result in marked clubbing of the affected root as shown in Fig 436 The irritant which affects the cementum affects also the adjacent bone, and it also tends to show an osteosclerotic reaction consequently extraction by forceps may be impossible. Such firm fixation should not be regarded as evidence of absence of active pathological changes.

In some cases, more particularly affecting the lower incisors, relatively large nodules of cementum are developed at the apices within what appears to be a chronic apical abscess for the bone is eroded around as in the latter

The most important common lesion affecting the tooth is inflammation of the periodontal membrane. This membrane is represented on the radiograph by the narrow space between the outline of the cementum and the outline of the condensed border of the alveolar bone the lamina dura (see Fig 434). Inflammation of the periodontal membrane may result in sclerosis of the adjacent alveolar bone but more commonly osteolysis, and one of the first indications that inflammatory changes are present is obliteration of the whole or part of the outline of the lamina dura.

The osteolysis may extend some distance into the alveolar bone and may involve

but for a request to the author immediately before the operation that he should give an idea of the extent of the bone involvement so that a graft the necessary size be cut from the iliac crest, a large part of the mandible would have been resected. In this case it was discovered later that the tumour was due to mumps.

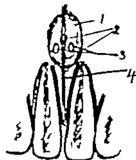


FIG 461 Diagram showing central incisors and the incisive foramen with its associated canals. (1) Incisive foramen. (2) Foramina of scarpa. (3) Incisive canals. (4) Median palatine suture

The pharynx, larynx, and trachea contain air a fact recorded on the radiograph by a dark shadow which indicates the calibre and internal outline of these structures This dark shadow may be projected over that of the mandible, and has been interpreted as that of an abscess tracking in various directions. The observer reasoning that the

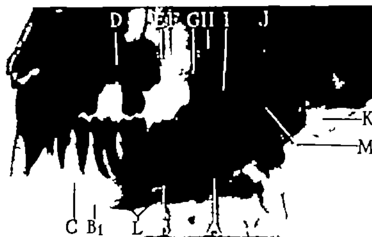


FIG 462. Mandible,

A. Angle of mandible
B. and B1 Mandibular canal.
C. Mental foramen.
D Floor of antrum.
E. Pterygoid hamulus.
F Transverse process of atlas.
G Anterior arch of atlas.
H Occipital condyle.
I. Odontoid process.
J Condyle of mandible
K. Mastoid process.
L. Hyoid bone.
M Posterior arch of atlas.

dark shadow must indicate pus because an apical abscess produced a dark shadow around the apex of a tooth. The importance of the relative density of the structures when radiographed had not been appreciated.

Fig 461 is a line drawing from a radiograph which shows certain normal structures liable to be misinterpreted.



Fig. 435 Radiograph showing sclerosis of the pericementum and increased thickness of the lamina dura of the second bicuspid with a normal antrum above



Fig. 436. Radiograph showing erosion of the lamina dura and adjacent floor of antrum which is infected. Hypercementosis of the adjacent teeth.



Fig. 437 Radiograph showing a subacute abscess involving the upper central and lateral incisors. Note the diffuse osteolysis and dissolution of the lamina dura around the apex of the central and on the adjacent aspect of the lat ral incisor



Fig 438. Radiograph showing a large apical abscess with sclerosis of it bony wall and erosion of the canine apex. The lateral incisor is root filled and there is a little erosion of its apex. (Chronic type f reaction.)



Fig. 439. Radiograph showing club-like expansion of the molar apices (hypercementosis) with a small area of osteolysis around the anterior root. (Toxic type f reaction.)



Fig. 440 Radiograph showing thickening of the periodontal membrane at the pices of the bicuspid and first molar with hypercementosis and sclerosis of the surrounding bone (Toxic type of reaction)

Radiographs of these large air cells (see Fig 403) show the apices of the canines, bicuspids, and molars pushing up the floor of the antrum which appears folded around them, and the ease with which such cells could be infected from the root canals of the teeth will be readily appreciated. Large infected cysts also occur in this area and may come to lie against or erode the wall of the adjacent antrum. The radiographic appearances of these septic foci have been interpreted as those of large normal antra. This mistake was made in the case shown in Fig 404 (For tuberculous cyst see p 503)

The dense shadow of the malar in the upper molar area and the shadow of the coronoid process has led to errors in interpretation which one finds it difficult to understand.

The radiographic appearance of the hamular process has led to the erroneous opinion that a fracture of the maxilla had been sustained

The alveolar bone may be markedly absorbed in pyorrhœa alveolaris even to the extent of denudation of the apices of the teeth (see Fig 405)

In other cases condensation of the bone is seen in the neighbourhood of the apices of the teeth which appear to be normal

These areas probably indicate the site of healed inflammatory foci. Odontomes of various sizes arising from different tissues may be detected from the radiograph. It is impossible to deal adequately with these lesions in a book of this size, and the interested



FIG 407 Adamantinoma of mandible

student is advised to consult one of the many excellent text books on Dental Pathology

In Leontiasis ossea the maxillæ and mandible may show massive development with dense bone (see Figs. 443 A and B pp 498–9)

Infected cysts similar to that shown in Fig 406 may be present in the edentulous patient, and radiographic examination of the jaws of such a patient is advisable when foci of sepsis are being sought after

Apart from the cysts which develop at the apices of infected teeth, two other common types of cyst may be encountered The simple cyst, commonly seen in the region of the angle of the mandible sometimes excavating the whole of its structure and having only a thin shell of bone has a very similar radiographic appearance to the simple cyst found in the shaft of the humerus and the upper third of the femur

In Fig 461 the incisive foramen is shown with its associated canals, the foramina of *Scarpa* and the median palatine suture.

The shadows of these bony openings are sometimes projected over or alongside those of the upper central incisor apices and in some cases the student will find it very difficult to decide the nature of the shadow for cysts and septic lesions at this site are not infrequent and may produce similar radiographic appearances. Care should be



FIG 463. Large loculi of the antrum extending to the alveolar margin in the molar area and showing the projection of the bicuspids and canine into the floor of the antrum. Note that the lining of the antrum is folded over the projecting apices.



FIG. 464 Large infected cyst extending from the anterior wall of the antrum eroding the apices of the incisors, canine and first bicuspid.



FIG. 465. Radiograph showing extensive alveolar and periapical absorption.



FIG 466. Large abscess at the apex of a retained root stump.

taken to study the continuity of the lamina dura, and if doubt still exists further radiographs should be taken with different angulations of the X ray tube.

Fig 462 shows the mental foramen This also with intra-oral films may be projected against the side of the bicuspid and produce the suspicion of apical abscess. The maxillary antrum shows a very marked variation in individuals. In some it is small and its radiographic appearance is obvious to the student, but in others it extends forwards as far as the canine and downwards almost to the alveolar border the roots of the teeth projecting up into its floor as in Fig 463.

has analysed the findings in 323 tumours of the jaws *Pancoast Pendergrass* and *Schaeffer* give an account of the injuries and pathological changes in the jaws.

Of the tumours of the jaw the adamantinoma (ameloblastoma) is best known. It is most commonly found in the molar area of the mandible in patients of middle life It has been less frequently recorded in the upper jaw the tibia, and as an intracranial tumour in the region of the sella. It is a benign tumour of slow growth—the patient may not seek advice for several years Solid and polycystic types have been recorded—the latter being the most common. In the mandible the tumour produces a localised cystic destruction, the borders and septa in which have slightly blurred outlines—it does not infiltrate the adjacent bone but some density of reaction may be seen in those borders which are adjacent to the normal bone—the borders of the tumour segment may be completely absorbed.

There is considerable variation in the size and multiplicity of the loculi which form the cystic type In some the appearances resemble a simple cyst, in others minute loculi are irregularly placed between multiple irregular loculi. All normal cancellous tissue in the area is destroyed. The lesions are sometimes mistaken for osteoclastomata.

The histological appearances are regarded as typical, but the author has known the histological and the radiographic appearance of metastases from squamous epithelioma to be mistaken for adamantinoma Some malignant tumours are classified as adamantinomata, but resection of the involved segment of bone containing the whole tumour eradicates most adamantinomata. Incomplete removal is followed by recurrences. Radiotherapy is of little or no value.

A remarkable case of a progressive, massive and very densely calcified tumour of the mandible is abstracted in a case published by *Burger* and *Lehman* The patient, a man aged 28 had had a large jaw all his life but at the age of about 25 he began to have pain, the right side of the mandible began to swell, and he began to expectorate pus and blood. Some dead bone was removed but a salivary fistula developed. Radiographs at 28 showed that he had a very thickened densely calcified maxilla obliterating the antrums and expansion of the mandible which contained irregular masses of densely calcified tissue. The walls of the sphenoidal sinus, the base of the skull posterior to this and the axis and atlas suggested infiltration by their increased density Many of the teeth were missing Considerable sloughing of dead bone from the maxilla and discharge from the fistula occurred during the next eleven years. A large rounded densely calcified tumour had grown from the mandible 32 × 22 × 22 cm. and it presented large superficial ulcerations on both the postero-lateral surfaces The dense bone in the maxilla by this time had disappeared but the base of the skull and upper cervical vertebræ showed increased deposit. The tumour now was resected. At the age of 41 he had a profuse hæmorrhage from an ulcerating epithelioma and died in a few months after from a second hæmorrhage (see Leontiasis ossea p 408)

It must be realised that any lesion of the jaw may become secondarily infected with tubercle bacilli or other organisms Failure to recognise this may result in disaster (see p 503)

The dentigerous cyst, which may also involve a large area of the jaw is to be distinguished by the appearance of one or more denticles in abnormal position. The possibility that the cyst may be tuberculous though containing an unerupted tooth should not be overlooked, for curetting may have disastrous consequences (see page 503). The author has published illustrated articles[7, 11] dealing with the significance of radiographic evidence of dental sepsis to which the student is referred for further details.

Excellent radiographs showing the stage of development of the teeth from birth to adult life and the more common pathological changes in the teeth and jaws will be found in the comprehensive book edited by *Norman Bennett*



Fig. 408A. Haemangioma of face. Note phleboliths and distortion of adjacent mandible



Fig. 408B. Radiograph showing the multiple lesions of polyostotic fibrous dysplasia in the mandible and the walls of the right orbit.

Osteolysis of the entire Mandible occurred as a result of sepsis in the case recorded by *J Steenhuis and J H Nauta*.—The patient was a woman aged 45 years. The process which took 2 years followed pyorrhoea.

Polycystic dysplasia, hyperparathyroidism, polyostotic fibrous dysplasia, osteitis deformans multiple chondromata and exostoses sarcoma and secondary carcinoma are conditions which affect any or all of the bones of the skeleton and may be associated with cyst like changes in the jaws. The student is referred to the description of these lesions in other bones. An interesting multilocular cystic condition of the jaws in a number of the members of a family has been described by *H A Jones C T Grachleter*

The astrologers satisfied themselves that the appearance of certain astronomical phenomena such as meteors, comets, eclipses etc., and the position of the planets at the time of conception influenced the development of these monstrosities. Others have believed them to be reincarnations of former human beings. In more recent times they have been attributed to bestial sexual perversion

Monsters Drawings and descriptions of conglomerate creatures purported to have been produced in this manner are to be found in abundance in the literature Even to-day like beliefs prevail in many places.

Ballantyne in 1894 stated that it is not very long since he received a letter from a distinguished member of the profession asking him whether in his opinion he thought it possible for a woman to give birth to a dog

We have no proof that monsters possessed any of these attributes or that their development had been or could be so induced. It is a common belief that these deformities are due to maternal or even paternal impressions. *Ambroise Paré* to whom we are indebted for many interesting and reliable accounts, has unfortunately mixed up with them such fictitious accounts as the following and represented them as facts.

He describes and illustrates monsters half human, half-animal, which were regarded as the result of maternal impressions or illicit intercourse between man and animal. Thus one monster is recorded which is said to have lived three days with the head shaped like that of a man, nose long and hooked like an elephant's trunk the hands and feet looking like the web foot of a goose, and a tail with a hook in it.

In 1720 *Mary Toft* of Godalming, Surrey England, achieved considerable notoriety throughout Surrey and even over all England by her extensively circulated statements that she bore rabbits. She was eventually watched and her deceit disclosed, but not until her statements had called forth considerable discussion.

Gould and *Pyle* state that there are no less than nine pamphlets and books in the Surgeon-General's library in Washington devoted exclusively to this case of pretended rabbit breeding

That there are credulous and imaginative people to-day who can believe in such absurdities is surprising but true.

In many cases in which the deformity was attributed to maternal impression investigation revealed that the latter occurred at a stage in the life of the fœtus when already the deformity must have been present, for it has been established that most skeletal deformities are laid down within the first 2 months from conception. A further argument against the defect being due to a maternal impression is that the latter bears little resemblance to the former though we all know that the impressions may be very different from the object which gives rise to them. There is no question that in many cases the mother seeking an explanation for a sporadic deformity tends to fix on any incident during the pregnancy which in any way suggests a relation to the defect. An instance of this is recorded by *Parrin* who pictures an individual with deformed extremities who might be classed as an ectromelus and was referred to as a "seal like monster" and the "Turtle man."

According to the story recorded by *Gould* and *Pyle* when the mother was a few weeks pregnant, her husband a coarse rough fisherman, fond of rude jokes, put a large live turtle in the cupboard. In the twilight the wife went to the cupboard and the large turtle fell out, greatly startling her by its hideous appearance as it fell suddenly to the floor and began to move vigorously The illustration shows almost identical appearances to those seen in the family exhibiting atypical achondroplasia, an account of which I published in the paper on "Dystrophies of the Skeleton." [24]

In most cases it is difficult or impossible for the outsider to appreciate any resem-

PART II

ABNORMALITIES AND PATHOLOGY OF BONES AND JOINTS GENERAL DISCUSSION

CHAPTER XXIII

DEVELOPMENTAL ABNORMALITIES OF THE SKELETON

Departures from the normal form of animal or human structure have always aroused either interest or curiosity repugnance or horror in all of us Unfortunately with the production of the radiograph much of the interest taken in these widely differing oddities ceases and except in a relatively few cases little further investigation is made

Frequency The frequency of these abnormalities of development is much greater than one would be inclined to suggest from an examination of the records of a hospital for not only do they exist in such minor degrees that the patient is unconscious of their existence, but well-marked abnormalities may be present unknown to the patient, or on the other hand be so conspicuous that the sensitive patient consistently avoids and resents their exposure in every way

Degree. Irregular development of every structure and organ has been recorded. Skeletal irregularities may take such minor forms as absence or excess of a phalanx, one or more teeth, small bone or epiphysis or tuberosity failure of fusion of an epiphysis with its diaphysis fusion of approximated digits dichotomous digits, malformed ankylosed or dislocated small joints.

On the other hand the abnormality may consist of widespread fusion and mal development of osseous structures or failure of development of the skull spinal column or limbs, or fusion of twins or important anatomical structures. The importance of the deformity and its subsequent development will be dependent on its site and physiological significance. Such abnormalities of the limbs may be unilateral or bilateral asymmetrical or symmetrical. They may be limited to one extremity be associated with similar deformities in other extremities or with irregularities of the trunk and skull. So varied are they in every respect that it is extremely difficult to classify them and it is probably because of this that many extraordinary maldevelopments have not been recorded or the significance of their relation to heredity been appreciated as widely as it might have been The more frequently we radiograph the whole skeleton and investigate all the members of the family the more frequently we find other defects and evidence of hereditary taint.

Causation. Descriptions of these malformations have figured largely in legends since the earliest times Historical accounts have chiefly concerned the gross deformities and these have been grouped together as monsters. A survey of the illustrations and descriptions of these early accounts will indicate that the imagination of the observer has played a very great part in their production for impossible creatures are therein portrayed But even to-day wild stories, which are equally ridiculous are circulated by credulous people concerning the birth and existence of abnormal children

It is not to be wondered at therefore that all sorts of explanations have been given to account for these abnormalities. They have been regarded as signs of the Almighty's displeasure Some were considered to indicate certain prophetic meanings while others were said to portend evil In certain instances the monster was attributed with the gift of healing.

"Segregation means that in a cross between two individuals which differ genetically that is, as regards their inheritance, in a particular character the offspring will belong to one type or other but will not inherit or transmit a blended condition between those of the parents." The various types of cell in the mature individual are produced by differentiation of the cytoplasm, the nuclei with their chromosomes apparently persist unchanged.

By *an orderly sequence* the cells which develop from the fertilised cell are correlated and differentiated to build up the body of the new individual.

The distinctive characters of the child will be those of its male or female parent, not a mixture of the two The features shown are referred to as the dominant features while those which are repressed are called recessive features If as the result of any influence changes are wrought in any gene, evidence of this will become apparent in the development of the individual and the defect produced by the mutation will be transmitted to some of the descendants.

The Laws of Mendel. The laws of heredity which were formulated by Mendel, indicate that certain characteristics transmitted from parent to child follow a Mendelian type of inheritance. Though the importance of this discovery has been taken advantage of by the breeders of animals it has not been given the significance which it deserves in the consideration of human activities As I have previously pointed out the inheritance of certain objectionable dominant characters becomes painfully obvious to inflicted parties by the regularity of their appearance in the offspring but the occasional and irregular outburst of an equally objectionable recessive character may not suggest an hereditary taint. The recessive factor is transmitted but, apparently lies dormant until the individual carrying it is mated with a person similarly afflicted. Then a proportion of the progeny will exhibit the recessive character Consanguinity of parentage obviously offers the greatest possibility for the outcrop of recessive factors and for this reason the intermarriage of cousins is inadvisable.

In the course of his routine examinations of radiographs, the radiologist sees examples of skeletal deformities, some so trivial that he feels they are not worth mentioning, *others so striking that they form the basis for physical defects which he is asked to* investigate by radiography It is perhaps not appreciated so much as it should be that the minor defects may have an hereditary significance which will afford considerable interest to those who care to investigate them. It will be found that the defects exhibited in various members of the family do not follow a definite pattern in some the extent of the skeletal deformity may be so slight as to be overlooked and the member accounted as normal, in others the deformities present a striking radiographic picture. Generally speaking most of these skeletal anomalies show a dominant character few a recessive character but each affected child shows a variation in the defects—they are not an exact copy of the affected parent.

It has been pointed out by *Ruggles Gates* that there are several characteristic features of a dominant character in human pedigrees, as seen in brachydactyly (1) Individuals showing the character are usually heterozygous (DR)—the chromosomes of the male or female parent only possessing the defective gene, the other being normal. (2) They usually *marry normals or individuals with the corresponding* recessive character and hence (3) half their children will show the dominant since the mating is DR × RR. (4) The character will appear in every generation, one of the parents of each family or sibship in the line showing it.

These various features usually make any extensive pedigree of a dominant human character recognisable at once as dominant and not recessive Human pedigrees of a recessive character are very different from those of a dominant, *i.e.* : (1) The character

blance between the defect and the impression which is considered to have originated it. Notwithstanding these arguments, some authorities would suggest that it is conceivable strong maternal impressions induced by shock during the early weeks of pregnancy may through the influence of some factor say the endocrine glands, bring about deformities of a severe degree. We know that the thyroid, parathyroid and pituitary have profound influence on later skeletal development, and it is conceivable that these or other glands may be adversely activated by strong maternal impressions during early foetal life, and these may check development at a vital stage and so result in defective growth. Evidence has been brought forward which suggests that certain infectious diseases of the mother may influence the development of the foetus.

The following incident, which I witnessed some 40 years ago, will serve to suggest that some of the monsters described in the early literature may have been due to false representation and ignorance of anatomical structure.

A medical practitioner sent to a professor at a university a small specimen with a note stating that the enclosed had been passed by a woman who was 3 months pregnant and that a similar object had been passed with termination of a pregnancy some 9 months before. The note went on to suggest that the professor would probably be glad to have the specimen for the university museum and it was for this reason that it was sent to him. The specimen created a considerable commotion and was referred to as the fish like embryo. It was a torpedo-shaped object about 1 inch long and of a light greyish colour and from near its middle a convoluted tubular structure emerged which appeared to end at a small lobulated mass. The latter structures were thought to be the embryonic umbilical cord and placenta. The specimen was seen by a man who had knowledge of the nature of the trick and the wonderful phenomenon dispersed like a wet squib when he described it as a disembowelled snail and his statement was confirmed by a zoologist. Who was responsible for the hoax was never established.

A careful inquiry into the development of these abnormalities indicates that the factors which influence skeletal development may be grouped into two main groups, *i.e.*, Heredity and Environment.

Heredity. Before we can appreciate the relative significance of these factors we must briefly examine the initial stages in the formation of the embryo. The embryo develops from the fusion of a male cell (the spermatozoon) with a female cell (the ovum). Each of these cells has a nucleus surrounded by protoplasm which is enclosed within a cell wall. It has been demonstrated that immediately preceding fertilisation the nuclei of these germinal cells each contains, in the human species, twenty four chromosomes. The fertilisation results in amalgamation of the twenty four male with the twenty-four female chromosomes so that the cell now has forty-eight chromosomes. When this cell splits into two daughter cells and at each subsequent division the chromosomes split longitudinally so that every cell which develops from the fertilised cell contains the descendants of twenty four male and twenty four female chromosomes. The mass of male and female chromosomes apparently do not fuse. They remain distinctive and it is now considered that they are the structures which carry the influences for the characteristic features and traits of the parents. These chromosomes would appear to be composed of a string of multiple ultramicroscopic genetic factors or genes. They have been likened to strings of beads, in which each bead or gene carries certain specific characters of the parent. According to the principle of segregation the chromosomes split longitudinally and do not fuse each cell of the embryo contains the individual elements of the distinguishing characters of both the parents and not a mixture of the elements.

Ruggles Gates has defined segregation in the following terms :—

scrutinising the miniatures of the chest to realise how variable is the heart shadow and the shadows of the main pulmonary vessels. The hip joint is no exception—we see all degrees of development of the acetabulum and corresponding changes in the femoral head, either as a concomitant variation in the pattern laid down or as a consequence of modification of stresses and strains. Familial variations are indicated in the same way as they are in the phalanges, *i.e.*, we see the influence of heredity though the pattern may not be identical. While the variations in the bones of the hand may not be followed by secondary changes defects in the structure of the hip joint, and other joints of the lower extremities, reduce the mechanical efficiency and the abnormal strains produce secondary changes In some cases the defect in architecture is associated with an inherited defect in the building material, with the result that more serious disturbances of function develop even at an early age. Such inherited defects are described in the next chapter

The members of the family chosen to illustrate one paper [44] were discovered when one member aged 19 was referred to me for radiography because of disability in both hip joints which had been regarded as bilateral Legg-Perthes s disease. The radiographs of the hip joints showed deformity of the femoral head and acetabulum as bilateral lesions which appeared to be of the same age period It is more common with bilateral Legg-Perthes s disease to see the affection in one hip joint at an earlier stage than in the other the similarity of the lesions suggested some general condition such as hypothyroidism or hereditary defect, and accordingly the whole skeleton was radiographed. The radiographs revealed irregular brachydactyly of both hands and feet, but no other abnormality These findings caused me to investigate the family

In each section of the first part of this book illustrations and descriptions will be found of many lesions which show familial distribution.

That heredity is a very important factor in the occurrence of developmental abnormalities is every day being more widely confirmed Skeletal and other defects have been exhibited in members of certain families for generations with a regularity which has established them as distinctive characters of these families. How the abnormality first arose we do not know but it must be assumed that some mutation of the essential gene or factor in the chromosome occurred as the result of some intrinsic or extrinsic influence, thus it has been proved that the progeny of mice which have been subjected to certain doses of X radiation all exhibit particular defects and these are subsequently inherited by their offspring A further note about this will be given under Environment.

Telegony There is a widespread belief in the phenomena of telegony by which one understands that if a pure-bred female is once fertilised by a mongrel, the female will be of no further use for the breeding of pure-breds, as all subsequent pregnancies will be contaminated by the mongrel strain. This belief has been the cause of the destruction of many good animals, but it will be obvious from the brief description of the process of fertilisation which I have given, that the belief is erroneous and every effort should be made to suppress it.

If telegony were an established fact, then the subsequent children by a second husband of a woman who had previously been married to a man transmitting hereditary taints would be liable to exhibit or transmit such taints and further pregnancies would be discouraged.

Lethal Factors. It has been established that certain lethal factors exist in the chromosomes of animals. These factors may be so slight that when mating occurs with a normal individual little harm becomes apparent, but if mating occurs with an individual who has also an hereditary taint, the combined effect may produce profound disturbances

suddenly appears in about one quarter of the children from a marriage in which neither parent shows the character (2) It is apt to be sporadic in its occurrence in any pedigree (3) It will not often occur in successive generations in the same line of descent but (4) if it does both parents and all the children will show it. It is known that consanguinity of parentage may bring out recessive characters which are hidden in the parents.

The investigation of families having members which exhibit hereditary defects entails considerable work. They appear to be more prolific than the normal, and the members to be interviewed and radiographed assume proportions which can seriously interfere with the normal working of the department unless you have successfully won the interest of all concerned. But even with the best and most willing workers there are many difficulties to be overcome. The patient in whom you originally discovered the hereditary taint may have sought help from the hospital because of some disability and careful attention to this will win the patient's confidence. Then enquiries as to any similar disability in his or her children or parents can be followed with requests for their attendance when the patient makes a subsequent visit for treatment. Some members of the family are very sensitive to the defects and resent any enquiry others have left the district and cannot be seen, others have been separated by feuds, sometimes apparently centred around the hereditary taint. Nevertheless it will usually be possible with care, to secure sufficient members in the different generations to make an interesting survey

Familial brachydactyly as illustrated in a paper by the author [44] may be exhibited in the members of a family unassociated with any other deformity The same can be said of bilateral coxitis. In another family described and illustrated these two conditions were associated with one another [44]

The skeletal defects in brachydactyly may consist of one or more short metacarpals, metatarsals, or phalanges. The distribution may be —

(*a*) Regular *i.e.*, all the terminal phalangeal diaphyses, the middle phalanges or the metatarsals may be stunted in growth, the terminal or middle phalanges may be missing or fused, or

(*b*) Irregular with isolated defective phalanges, metacarpals or metatarsals.

It was shown that, though all members may inherit stunted development of some of these bones, they did not exhibit an exact copy of the parent, *i.e.*, there was variation in the defects.

The variations exhibited in different members of a family may be striking and spectacular and should help us to realise that the variations in the structure of each one of us are infinite—sufficiently characteristic to permit of identification. We have learnt to appreciate *the infinite variety in finger prints, but we do not realise, as fully as we* ought, that this feature characterises *all* the structures of the body *i.e.*, *there is no* fixed normal. It was because we assumed that the stomach had a common normal shape that we made the mistake of submitting patients with variations of the "normal" to operative interference Even to-day with the introduction of new methods of visualising anatomical structures we tend to assume that the normal conforms to the "regular" pattern which we have seen in the first few cases, instead of considering the possibility of infinite variety the extremes of which may be grossly different. In other words, we have not learnt the lesson taught as long ago as 1858 by *Darwin* and *Wallace* *i.e.*, "All creatures tend to vary appreciably No two individuals are exactly alike and some are distinctly unlike within the same species."

The difference may be apparent only to the trained observer the members of a flock of sheep all look alike to the town dweller but the farmer knows the characteristics of each one and can readily demonstrate them. One has only to spend a few hours

that a great proportion of these pregnancies result in defective development of the embryo, serious enough to be incompatible with life, that such sites are detrimental to normal development

It is possible that such sites either do not permit of adequate oxygenation of the embryonic tissues or that the inter reactions between the cells of the embryo and the cells of the site of the abnormal implantation are irregular

Naturally for the healthy and orderly development of the embryo it must establish healthy attachments to the uterus. Anything which tends to prevent the embryo at any time from obtaining its essential oxygen and food supply and disposing of its waste products will probably affect its growth more particularly of those parts or tissues which at that time are undergoing active cell division and differentiation. We have reason to believe that the growth of a cell is influenced by the activity of its neighbours. Undue activity or suppression of certain cells may therefore have a very important bearing on the development of the embryo One would not be surprised therefore if disease of the maternal tissues at the site of implantation of the embryo led to developmental defects in the embryo From the time that the embryo becomes implanted in the uterine wall until the birth of the infant, the maternal blood supply through the agency of the placenta provides the oxygen and food supply and removes waste products necessary for the progressive growth of the new being Here again one might expect that the foetus would be adversely affected by any deleterious substance circulating in the maternal blood or by injury to the placenta For the greater part of its life the young animal is suspended within the amniotic sac in a fluid medium having the cord as its only attachment to the walls, and is thus protected from localised pressure or trauma and kept at a uniform temperature Pressure on the growing parts by the cord or by bands or folds of the amnion have been held to be responsible for the deformities referred to as "congenital or intra-uterine amputations."

While the protection against trauma is sufficient to safeguard the foetus during any mild injury to the mother there is a limit beyond which trauma will injure the foetus, for from time to time radiographs of newly born babes show fractures which have healed or are in the process of healing

What evidence have we that environment can act in the way which has been indicated ?

During the past few years a great deal of experimental evidence has been provided which supports these suggestions.

It has been shown by experiments on the developing embryos of lowly forms of animal life that if one of the cells resulting from the primary division of the fertilised ovum is damaged and left attached to its fellow its growth is suppressed but the undamaged cell develops into the corresponding half of an embryo whereas if the two cells are completely separated both of them develop into complete embryos

Even after the third division which has resulted in a mass consisting of eight cells, complete separation of these cells into individuals has been followed by their development into eight embryos, each showing normal structure but somewhat reduced in size. Other experiments have indicated that the development of multiple embryos may be initiated at an even later stage namely after the formation of the blastoderm, for while the single foetus develops from one invagination point of this structure, multiple foetuses will develop if the blastoderm can be induced to produce multiple invaginations of this character Such experimental results would seem to indicate that the early cells are equipotential and that it is their separation which leads to the development of like twins, triplets, etc. It has further been shown that as development proceeds the cells lose their capability of separate development.

such as early disintegration of the foetus, the development of monster or other serious developmental defects Thus *Mohr* and *Wriedt*, in an account of a short fingered family (Brachyphalangy) give an instance of the mating of two similarly affected persons. The intermarriage produced a cripple which had neither fingers nor toes, was unable to develop and died at the age of 1 year

The question arises as to how these deformities due to mutations die out, and a number of causes suggest themselves. In some the deformity may be repulsive and mating rendered impossible. The deformity may co-exist with an enfeebled constitution. It may be associated with certain lethal factors which may lead to early death of the afflicted foetus

As pointed out by *Lovatt Evans* "In respect of many qualities, the Mendelian idea of dominance seems to fail Thus in man the progeny of a cross between a white and a black race are more or less intermediate between the two and vary according to the amount of black and white blood introduced in succeeding generations. Definite black and white individuals are not produced but merely individuals of various degrees of brownness. This is known as blending"

Deformities due to Environment. We have seen from the previous account that for the development of a normal individual we must have male and female cells which are free from any hereditary taint. Not only must all the genes for the development of every character be present in essential details, but these must not have been altered in any way and the factors controlling their development must be able to function normally *But we require not only a normal heritage but also a normal environment if* the new individual is to be normal. That is to say the habitat of the cells which are to fertilise or become fertilised must be healthy and virile.

The fertilised ovum must be (1) maintained at an equable and suitable temperature (2) protected from any trauma, (3) supplied with an adequate supply of oxygen and food free from any injurious factors. Defects in any of these essentials will tend to check or alter development and so lead to abnormalities. Even if these essentials be defective during a period only of the life of the embryo the development of such structures as are undergoing active changes at that time may be seriously affected, for it has been established that the growth of a cell influences and is influenced by the activity of its neighbours. We may therefore expect that any serious constitutional disturbance or disability in the parents may lead to defective development of offspring because of damage to the germ cells. Thus in any condition in which the blood of the parent contains deleterious substances such as bacterial toxins or poisons of any sort the germ cells are possibly adversely affected

It would also seem reasonable to believe that the virility of these cells is adversely *affected by immaturity and with increasing age of the parent.* Fertilisation of the ovum is usually believed to take place in the Fallopian tube. Immediately after it begins to show active division. For the first 7 or 8 days the fertilised ovum, the embryo is still free and is carried, by ciliary movement or peristalsis, generally to the uterus. The active division and redivisions of the primary cell has now produced a small mulberry like mass of cells and this becomes adherent to the wall of the uterus. During its free state the embryo is dependent upon the small store of food stored within the ovum and the surrounding discus, and on the fluid which bathes it in the Fallopian tube. The free embryo may be damaged by trauma, though it is difficult to conceive how trauma could be directed against such a well-protected structure It is known that the embryo becomes attached sometimes to the Fallopian tube to the peritoneum, or to the ovary and ectopic gestation results It may be that the embryo has been forced to these abnormal sites by trauma or disease of the maternal tissues. We know from the fact

DYSPLASIAS AND DYSTROPHIES OF THE SKELETON

The developmental irregularities considered in the previous chapter were essentially defects in the architecture or skeletal pattern. Ossification of the bones is normal but, because these defects are frequently associated with asymmetry and imbalance, secondary changes develop as the patient is subjected to the stresses and strains of adult life. There are however hereditary defects which primarily affect the building material any deformity in the skeletal pattern being dependent upon the inability of the bone to withstand the normal stresses and strains of function and irregular or excessive growth of the aberrant tissue. These dysplasias show very considerable variation in the degree of their severity: some are so severe as to be incompatible with a separate existence, consequently they number among the stillbirths. Some survive birth but are unable to live beyond infancy while in others the severity may permit of life to adolescence or even old age. Many "transitional" forms occur which are difficult to classify.

Ossification of the whole skeleton may be abnormal and defective as in **Osteogenesis Imperfecta** or **Albers-Schönberg's Disease**. The metaphyseal growth may be principally affected as in **Achondroplasia** and **Chondro-osteo-dystrophy** or though the defect may involve the whole ossification, it often affects only one side of the skeleton, or isolated sites in multiple bones or just single foci, the remainder of the skeleton being normal. The lesions in the latter dysplasias may be due to the proliferation of the mesoblastic cells in any stage of their existence thus we have **Polycystic dysplasia**, **Polyostotic fibrous dysplasia**, **Chondro-dysplasia**, **Osteo-dysplasia**, **Melorheostosis**, **Angiomatosis**. These localised foci of aberrant tissue are apparently not subjected to the paring of the periphery as is the normal bone consequently proliferation of the cells results in expansion of the focus often to the detriment of the stability of the normal bone which may readily fracture. In some cases the lesions diminish in size with age but by metaphyseal growth recede from the extremity towards the middle of the diaphysis. In other cases proliferation of the abnormal cells produces a neoplastic appearance. Localised resection, if complete, eradicates the focus. Malignant metaplasia has taken place in some lesions of all the types.

OSTEOGENESIS IMPERFECTA (see Figs. 14, 34, 157, 158, 217, 378 and 437)

Osteogenesis Imperfecta. Osteogenesis Imperfecta was the term coined by *Vrolik* in 1845 to describe a dystrophy of the fœtal skeleton which was characterised by imperfect ossification and abnormal fragility. Most of the other osseous dystrophies have some representatives which are apparently incompatible with life while others show the disorders in lesser degrees of severity. It is presumed, though there is no absolute proof of it, that this condition described by *Vrolik* is the gravest form of the dystrophy which when compatible with life, was formerly given the names of **Idiopathic Osteopsathyrosis** (*Lobstein*, 1833), **Fragilitas osseum**, and **Hereditary Fragility of Bone**. It is considered that these terms should be dropped and the term Osteogenesis Imperfecta be extended to include the fœtal, infantile, adolescent and adult examples of the disorder.

There are other conditions of bones, to which reference will be made under differential diagnosis, which present clinical and/or radiographic features indicating *imperfect* ossification or abnormal fragility of the bones, but these have not the clinical and radiographic features which characterise the group for which it is considered *the term* osteogenesis imperfecta should be reserved.

This dystrophy shows a familial distribution, and in these families the affected members usually show characteristically blue sclerotics associated in some cases with deafness *said to be due to oto-sclerosis. Conrad* and *Davenport* consider it to be one of

examined and the congenital defects noted in the descendants of X rayed mice included various types of club feet, syndactylism, hypodactylism, congenital amputation and polydactylism. The abnormalities were examined by abdominal section at varying ages during gestation.

He states that these embryological studies have shown that the earliest foot defect is associated with the formation of a blister like bleb which raises the epithelium of the foot, usually in a localised area. This condition is usually found during the twelfth to the fifteenth days of prenatal life, and is followed by the escape of blood into the bleb and the formation of a localised blood clot. These blood clots may persist until birth.

He further states that young rats irradiated *in utero* showed profound arrests in development. In a few instances mothers that were treated several days before mating with normal males gave birth to offspring showing peculiar lesions similar to those seen in young animals irradiated *in utero*

Bean who also carried out researches with the descendants of X rayed mice, does not refer to the association of blebs or hæmorrhages with the congenital defects, but considers that the latter result from a developmental arrest caused by failure of the blood or nerve supply This experimental evidence of disturbances in growth as the result of X-radiation has been confirmed clinically Atrophic changes have been noted in the bones of young people who had been subjected to radiation.

W S Newcomet records that in a case of multiple hæmangioma of the finger the radium radiation had apparently no effect on the tumour but the phalanges radiated failed to develop and consequently remained shorter than the phalanges of the untreated hand.

J D Bisgard and *H B Hunt* record the details of 2 cases in which deformity resulted from retardation of growth by radiation.

Mall, after examining some 2,000 human embryos, came to the conclusion that faulty implantation of the embryo plays a very important part in the development of these anatomical defects for he found twice as many monsters in ectopic gestation as in uterine. Of 40 ectopic children investigated by *Werder* 18 died within a week of birth, 5 within a month, 1 at 6 months, 1 at 7 months, 2 at 11 months, and 1 at 18 months. We may fairly assume from the great proportion of normal births that the human embryo has the capacity of overcoming many of the damages which beset its growth.

The conclusions to which we come as a result of our experiences in endeavouring to ascertain the cause of the many and varied developmental defects find some support in these experimental findings. It is perhaps because of the variety of defects and the infrequency of the activity of the like deleterious factor that we tend to lose interest in them and that the parent, failing to get any reasonable explanation from us, seeks it in some maternal or paternal impression.

In the investigation of these defects we are probably not put in possession of the full details.

Temporary illnesses of the mother involving profound metabolic and endocrine disturbances may be forgotten drugs and metallic poisons may have been taken (the action of which on the embryo we do not know) injuries may have been sustained early in pregnancy and been forgotten. Local disease processes may exist unsuspected. These and many other explanations have been considered, but, as before stated, it is rare for the investigator to get the same explanation in two cases.

As in all other bone lesions we should improve our knowledge if having individually carefully investigated all our cases, we collectively pooled our results. For further references see author's papers [33, 44, 45]

serial radiographs of the whole skeleton of a number of typical and representative cases of all ages.

Radiographic Appearances. From a study of the radiographs of these cases it would appear that in the fœtal type except for the cortex of the bone, ossification does not proceed beyond calcification of the cartilage consequently the skeleton is unable to withstand the crushing effect of labour and multiple fractures result.

In the less severe dystrophy multiple fractures may occur during childbirth but the infant survives. Beyond a general lack of calcium indicated by the lack of density the bones approach the appearance of normal bones. The most noticeable feature is the expanded extremities of the long bones with perhaps some flattening out of the rib curvature and increased curvature of the long tubular bones of the extremities. At this stage the metaphyses may appear to be normal—the diaphyseal and epiphyseal borders being clearly defined and regular and the space occupied by the growth cartilage of normal dimensions and appearances. As the patient approaches puberty marked changes occur in this region. The metaphyseal borders become irregular there appear to be excavations into the diaphyseal and the epiphyseal bone which have clearly defined borders these may gradually develop until we see multiple rounded islands of non ossified tissue within the epiphyses and the diaphyseal extremities These islands have denser walls than the neighbouring bones and suggest calcification in the fibrous tissue capsules of cartilaginous nodules. They indicate that the case is truly one of osteogenesis imperfecta, for normal ossification in the growth cartilage is practically non-existent. As the patient approaches adult life this abnormal ossification is represented by a very irregular open mesh cancellous tissue in the extremities, which though within normal measurements, appear from the slender shafts to be markedly expanded The slender shafts show little cancellous tissue—in fact they may appear to be composed of solid rods of compact tissue with little or no medulla. In some cases the lower limbs become so atrophied and deformed that amputation has been performed. Such severe changes appear to be more pronounced in the lower extremities—ossification of the upper extremities proceeds at an almost normal rate though the hands often show but a thin cortex to the tubular bones and the humeri marked curvatures

In some cases isolated patches of densely calcified bone may be found in the cancellous extremities of the long bones.

The typical changes have been described and illustrated in various parts of the skeleton the spine, see p 409 the pelvis, see p 323 the skull, see p 486.

Fractures are common. Practically every bone in the fœtal type is crushed but in lesser degrees of the dystrophy while some escape fracture during childbirth, others sustain one or more fractures These readily consolidate The fractures which recur in infancy and later may be complete and lead to separation and displacement of the fragments such fractures usually consolidate at normal rate a feature seen in those subjected to surgical osteoclasis. Other subperiosteal fractures may extend partly or wholly through the bone These tend to be associated with an ever increasing reaction in the bone bordering on the fracture Dense bone may be laid down, often for some distance around the fracture but consolidation does not take place In one case 7 years after fracture the fragments had not consolidated. It will be noted that the incomplete fractures are different from those seen in such conditions as **Rickets Renal Rickets, Osteomalacia Paget's Disease**, etc In these the incomplete fracture is on the convex aspect of the curved bone, where the bone is relatively osteoporotic and exhibits little reaction, whereas in osteogenesis imperfecta the incomplete fractures may occur on the concave aspect at the key point of the curvature where compression is greatest and they are associated with a reaction of dense bone. For illustration, see paper by author [44]

the best examples of hereditary transmission of a pathological condition. As with other dystrophies there are isolated examples of this which do not appear to be due to hereditary taint. In these the fragility is not associated with blue sclerotics; but it should be noticed that blue sclerotics have been seen in patients who have not exhibited any abnormal fragility of the bones. Segments of bone removed from fœtal, infantile, adolescent and adult examples of the dystrophy have been subjected to histological examination by a number of independent observers. Because of the small amount of tissue examined, the variety of sites from which it was chosen, the degree, phase and nature of the condition examined, the reports indicate very considerable differences of opinion.

Further contributions to the confusion has been due to the lack of uniformity in interpreting the histological appearances. Consequently we must look elsewhere for evidence which will permit us to decide the degree, phase and nature of the bony changes in individual cases and to classify them. Radiography affords this evidence. It permits us to study the whole skeleton at any one time and by periodical examination to watch its development throughout the years and the effect of function and any complications which may occur. By a careful co-relation of the radiographic and histological features in many abnormal types of bone the author is of the opinion that from the radiographic evidence it is possible to gain a very good indication of the nature of the tissue changes and anticipate the histological structure in different sites, *i.e.*, in the fœtal form the radiographs show a skeleton, the elements of which have a thin shell of bone for a cortex, the internal structure showing a granular appearance indicating calcification rather than ossification; the infantile examples in some cases show in the diaphyseal and epiphyseal regions of the metaphysis multiple rounded bony cell-like structures up to $\frac{1}{4}$ inch in diameter enclosing non-osseous tissue; the appearance is similar to the lobulated cartilaginous structure we see in ecchondroses; the adolescent and adult examples show slender shafts composed almost entirely of dense compact tissue while the expanded extremities are of a coarse cancellous tissue. Though many cases show similar progressive clinical developments the radiographs indicate very material differences in the behaviour of the bone in others (see Figs. 157, 158).

In some the changes are similar throughout the skeleton, usually more marked in the lower extremities, but in others you may see a very thin skull associated with changes in the bones of the hands and feet, some degree of general osteoporosis, bending and flattening of the ribs but little else.

Ossification in this dysplasia appears in early life to be in advance of the normal, *e.g.*, we may see ossific nuclei for the femoral capital epiphysis within the first three months of extra-uterine life and epiphyses for the superior and inferior rims of the vertebral bodies as early as the fourth year.

Osteogenesis imperfecta in late adult life is obviously associated with less marked dystrophic changes and more active function. It is probably due to the latter in association with a certain amount of plasticity of the bone during infancy and adolescence, that the spine, pelvis and lower extremities show the pronounced curvatures which appear to consolidate in early adult life and exhibit little or no progress in the deformity in later life.

Laxford Knagg's case (8) lived to the age of 68. He had fractures at birth but after this and until 40 years of age, he lived a relatively normal life though his limbs were deformed. At 40 he became poverty stricken and his limb bones developed great fragility. It is possible that this apparent recurrence of an active phase of the dystrophy was due to a superadded hunger osteomalacia.

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The author [44] has published his observations made from a comparative study of

osteogenesis imperfecta, typical evidence of which is shown on the bones, the hæmatoma becomes ossified and forms a loose mesh cancellous involucrum around the original shaft which is gradually absorbed (see Fig 470 B) This bulky osseous mass is not absorbed but persists into adult life and leads to the erroneous diagnosis of single or multiple exostoses. Four examples of this relatively rare complication in osteogenesis imperfecta have been seen and recorded by the author [48]

In one case a patient of 30 years of age sarcomatous metaplasia developed within the ossified hæmatoma at the lower end of the tibia and he died with metastases within a few months

Since the publication of these 4 cases, the author's attention has been drawn to a subsequent paper by *S L. Baker* who has recorded 2 other cases In both a biopsy was performed, at 3 and 8 weeks respectively of a fracture being sustained because the tumour-like masses (such as are shown in Fig 470 A) were considered to be sarcomata—despite the extreme rarity of sarcoma being initiated by fracture He gives a well-illustrated description of the abnormal tissue His "interpretation of chondro-sarcoma" he regards "as a not unjustifiable diagnosis. He further records that "disarticulation at the hip joint was considered but regarded as too risky and of doubtful value and palliative X-ray treatment was decided upon." The patient recovered and his later radiographs showed the same typical appearances as were illustrated by Fig 470 B but as he stated, "Had the leg been removed in my Case 1 it would have been impossible to prove that it was not a sarcoma" It would appear therefore that biopsy in these lesions carries not only its own inherent dangers but the very serious risk of misinterpretation of the histological structure even by experts risks which could be avoided, as in the 4 cases recorded, by appreciation of the typical radiographic features. After a later review of the histological material, when the lesion of his Case 1 was resolving *Baker* regarded it as hyperplastic callus which he conjectured may develop in two ways : "(*a*) an outgrowth of a mass of cells derived from the periosteum and fractured bone ends which extends like a tumour and infiltrates and replaces the normal tissues or (*b*) the spread of a reaction (presumably initiated by a chemical stimulus of some sort) which extends like an inflammatory process."



FIG. 470B. E. R., May 11th, 1939. Osteogenesis imperfecta associated with infantile scurvy Note the periphery of the ossified subperiosteal hæmatomata have replaced the normal shafts. The typical changes of osteogenesis imperfecta are shown in the region of the growth cartilage

Fracture through the unossified zone at the diaphyseal extremity which leaves the epiphysis, and its growth cartilage with the densely calcified surface of the diaphysis intact, while the diaphyseal extremity tears through the periosteum to be displaced outwards, is not uncommon at the upper end of humerus and femur and lower ends of the tibia and femur (see p 203 (*Fig* 180))

Complications. The affected patient in some cases shows, in addition to the features of osteogenesis imperfecta a condition suggesting scurvy subperiosteal hæmorrhages



Fig 470A. Radiograph (April 7th, 1936) of ossifying hæmatomata in case of osteogenesis imperfecta (a girl, E. K., born February 11th, 1933). Note that the ossification is more advanced in the older lesions on the left and the more marked tumour indicated by the soft tissues over the more recent hæmatoma on the right.

being more frequent than fractures. In infancy calcium deposits in the subperiosteal hæmatoma show that the periosteum had been stripped from the bone in some cases throughout its whole length, and between it and the bone large collections of blood are present (see Fig 470 A) The epiphysis is apparently not involved, though the capital epiphysis of the femur or humerus may before calcium is deposited in the hæmatoma appear to be retained in the acetabulum while the upper end of the shaft is displaced outwards and upwards Though in this early phase the radiographic appearances suggest **Infantile Scurvy (Barlow's Disease)** the subsequent radiographic history of these lesions show that another factor—presumably the osteogenesis imperfecta —is active For in the subperiosteal hæmatoma of scurvy the calcium is deposited the clot is organised and then gradually absorbed, leaving no trace of its former existence In the presence of

uniform radiopacity of the bones and not because he had knowledge that the bones possessed any other physical characters of marble More recently doubt has been cast on the wisdom of the use of this term, for the condition is often associated with fragility of the bones. In one case which came under my notice the femoral shaft was fractured during the application of a tourniquet.

Pirie who has published the details of 4 cases, had the opportunity of examining the physical characters of affected bones, and he states "I drilled a normal femur 8 inches from the knee joint and a corresponding thickness of marble bone at the lower end of the diaphysis of the femur picking out the densest part I could find. I exerted, as nearly as I could, the same pressure in each case It took twenty three turns of the handle of the drill to get through the normal bone and only seven turns to get through the marble bone The feeling caused by the cutting edge of the drill was very different in the two operations. With the normal bone the drill cut with a sharp cutting sound, but in the marble bone it sank in as if boring into chalk. On using my penknife on the marble bone I found it cut like chalk and not at all like marble and I felt inclined to call them chalky bones and not marble bones. "

This is in distinct opposition to the opinion expressed by *M S Henderson* in a discussion at the Mayo Clinic, in which he stated : "In the cases operated on the bones are so hard that they break the edge of the chisel or the drills."

Alexander also supports the latter opinion by publishing a radiograph and stating that it shows a nail which had been used for pegging a fracture of the upper end of the femur "sheared into two pieces." It is difficult to understand why a chisel or drills were used in this disease

At a meeting of the British Orthopædic Association in Edinburgh in 1933 I had the opportunity of inspecting a piece of the skull which had been removed by *Dott* from an affected patient, one of a family of four showing the same bone changes. This fragment was about 1 inch thick, much heavier and stronger than chalk, but not of the hardness of ivory

It would therefore appear that affected bones vary in hardness according to the age of the patient. In childhood and adolescence affected bone is usually associated with fragility but in patients who have survived to adult life, though this liability to fracture exists, it is not such a prominent feature.

This dystrophy has also been described under the following names Osteopetrosis, Osteosclerosis fragilis generalisata, Congenital Osteosclerosis.

It is a rare condition, and about 120 typical cases have been described in the world's literature since *Albers-Schönberg's* original communication in 1904 A number of cases have been described as such which do not present the typical radiographic appearances.

In common with some other skeletal dystrophies heredity appears to be a very important factor

Of the few writers on this subject the majority have described several affected members of a family *Pirie* recorded the disease in a mother and her three children and *Duncan White* in four members of one family In some cases the hereditary taint is apparently brought out by consanguinity of the parents. In this respect the case recorded by *Alexander* is interesting His patient, a woman of 43 years, belonged to the fourth generation of parents on her mother's side who were cousins, *i.e.*, her mother and father were cousins, the mother's mother and father were cousins, and the grand mother's mother and father were cousins.

Age The disease has been discovered by radiography as early as in the foetus *in utero* while in other cases it has escaped detection until adult life Those discovered

The material from which he deduced that this was callus originating in one of these ways was obtained at the biopsies made 5 and 8 weeks after the fractures had occurred, during which time, as we well know considerable organisation could have taken place. At a recent meeting of the British Orthopædic Association he showed a magnified radiograph of callus which he considered showed the earliest radiographic sign of the abnormal tissue as woven bone. This opinion is opposed to the author's radiological experience with these fractures. Serial radiographic appearances from the date of fracture or discovery of a tumour mass show that the first sign is a cloudy deposit within the tumour which gradually assumes a granular appearance and a density far greater than that seen in callus or in new bone. The outlines of the mass are soon, for the most part, clearly defined and its periphery rounded. The serial radiographic appearances are those of an ossifying hæmatoma such as are seen in the hæmatomata of scurvy. In both of these conditions hæmatomata and fractures are produced by trivial trauma or even normal function. When the scurvy is a complication of osteogenesis similar effects can be expected.

These serial radiographs permit of study of the whole of the developing lesion without causing the patient any pain or risk, whereas the material for histology can rarely be reasonably obtained, certainly not in the early stage during which repair processes must be very active and not more than once in the evolution of the lesion, and even then only very small microscopic fields can be examined, rather than the whole lesion and its environs. It was the serial radiographic appearances which did indicate to the author the possibility of a superadded complication of the osteogenesis imperfecta, *i.e.*, scurvy and in a subsequent case an infant of 3 months in whom a mass developed in the thigh which was clinically diagnosed as a sarcoma referred because her radiographs showed a large dense granular mass enveloping the most part of the femoral shaft, the diagnosis of an ossifying hæmatoma was made and advice given that vitamin C should be administered. In less than three weeks it was recorded on the case sheet that "baby is contented, takes feed well, and is putting on weight at a normal rate. Progress confirms that this is an ossifying hæmatoma and not an osteosarcoma," and the radiographs indicate that the mass is showing considerable ossification—its periphery is well-defined but irregular it has lost some of the density of the calcification, and is showing the characters of new bone. The possibility of confusing these radiographic appearances with the slow-growing chondrosarcoma must be borne in mind by those who have not made themselves familiar with the clinical features of these lesions. In one case a patient of 30 years of age sarcomatous metaplasia developed within the ossified hæmatoma at the lower end of the tibia.

Lanford Knaggs, Sicard, Paraf and *Bize, Levander, Muckley, Hein, Fairbank, Gela* and *Collonna* have published radiographs illustrating cases of this disorder.

ALBERS-SCHÖNBERG'S DISEASE (see Figs. 81, 82, 114 and 162)

In 1904 *Albers-Schönberg* reported on an unusual radiographic appearance of the bones of a man aged 26 years. The radiographs showed that the cancellous structure of the bones had been replaced by dense chalk like material. The general outline of the bones was not markedly changed, but the medullary cavity of the long bones was obliterated. The patient was an intelligent man, who was apparently quite healthy and had always been so. This patient was examined and radiographed 11 years later by *Reiche* who recorded that the mental capacity of the patient had been reduced and that he now had a very pale complexion, but that no marked changes in the bones had taken place in the interval.

Albers-Schönberg called the bones Marmorknochen or Marble bones because of the

be seen. The bones at the base of the skull show increased density and thickness, the small bones of the carpus and tarsus show accretions of dense bone forming their peripheries.

As will be seen from the illustrations of *Pirie* to these zones of dense bone further accretions are added with age, and if the child survives to adolescence the typical changes which I have described will be present. In some cases, such as those described by *Pirie* and by *Schinz*, the radiographs show that the fœtal or infant bones though normal in shape are already uniformly dense. This suggests that the abnormal ossification began with the transformation of the cartilaginous skeleton. By the age of 2 years the long bones may present the typical clubbing and density.

Fractures of affected long bones are not uncommon. As in *Paget's* disease they resemble the fractures of sticks of chalk, that is, they are transverse. Union without excessive callus in the normal time is the common result, but as in normal femora non union may result in the adult if a fracture of the neck is sustained.

The author has seen a number of cases in which no abnormality of the skeleton was suspected until adult life when radiographs were taken for some other reason, perhaps fracture, and the unusual density of the bones was detected. Further radiographs of the skeleton in these cases will show that the condition is a generalised one but, as the dystrophy is of a mild degree the long bones show a medulla, but a cortex of greater thickness than normal. No sign of the denser transverse lines of accretion, which characterised the adolescent state, will be seen. The bones may show no marked departure from the normal, there may be no clubbing of the extremities at the knee joint as we see in the typical case, but the tubular bones of the forearm and hand may be devoid of th graceful architecture of the normal by an increase in bulk, particularly of the cortex, nature appears to have tried to make up for the lessened strength of the abnormal bone.

In a woman, aged 42, who had sustained a fracture of the middle third of the femoral shaft the radiograph provided the first evidence of the dystrophy. She had a brother and sister who were apparently quite normal and there was no consanguinity of the parents. The patient had had no illness and was apparently quite healthy until her accident. Radiographs showed some thickening of the base of the skull but no changes in the vertex. The ribs and clavicles, scapulæ and upper halves of the humeri were typical but little departure from normal could be detected in the lower half the radii and ulnæ. The middle and proximal phalanges show an increase in the thickness of the cortex and the trabeculæ of the cancellous tissue were coarser than normal. The pelvis was normal in shape but its density was markedly increased. The femora were of stouter build, the cortex thick and the cancellous tissue coarse. Little change in the tibiæ and fibulæ or the bones of the feet.

The teeth may be late in erupting and, owing to their defective structure, show caries at an early age. In the case described by *Shallow Davis and Farrell*, extraction of a molar was followed by multiple alveolar abscesses and eventually complete sequestration of the mandible occurred.

Kerr reports a typical case of Albers-Schonberg's dystrophy in a negro of 20 years in whom sarcomatous changes developed in the lower third of the femur from which he died 6 months later.

M. Peak has recorded 8 cases. A grandmother aged 74 years, her two daughters and five children of one of these daughters. A sixth child of this daughter does not show the dystrophy. The other daughter has two apparently normal children. The dystrophy appears to be transmitted by both sexes. No enlargement of the liver spleen or lymph nodes were noticed in these cases and only a slight anæmia.

early in life have been brought for medical examination because of hydrocephalus, nystagmus, paralysis of eye muscles, blindness, necrosis of the jaw carious teeth, gingivitis glossitis, under-development, or spontaneous fractures whereas in adolescence and adult life spontaneous fractures, cranial nerve palsies and progressive anemia have been the dominant factors. Other clinical findings include enlarged spleen and liver and often neuritis.

The diagnosis rests upon the radiographic appearances now to be described.

Radiographic Appearances. The most characteristic picture simulated by no other disease, is seen in the affected adolescent. The most rapidly growing extremities of the long bones show the most marked changes, namely the lower thirds of the femora and radii, and upper thirds of the tibiae and humeri These extremities are composed of dense bone in which no cancellous trabeculation can be detected, and as far along the shaft as this change has occurred the bone is expanded and club-like in appearance If hard rays are used in taking the radiographs, multiple closely packed transverse lines parallel with the metaphyseal growth cartilage will be seen indicating that the accretions of dense bone are laid down as such from the growing cartilage, the epiphysis as well sharing in the transformation. The non-ossified metaphyseal cartilage is no thicker than normal, its dense bony borders are clearly defined, unless grave metabolic changes apart from this affection are present.

These features can best be studied in the radiograph of the hand (see Fig 8). There it will be seen that the phalanges show no differentiation into cortex and medulla in fact, no suggestion of cancellous tissue and medulla can be detected. The bones are dense and of a closely packed granular structure. They do not show the homogeneous density of normal compact bone. The growing expanded extremities show the multiple accretions of dense bone and may also show what I have described as cracks extending from the metaphysis and vertical to it into the affected extremity of the diaphysis. Though the distal half of the phalanges may be of normal shape and devoid of the dense bony accretions there is no evidence of medulla, cancellous or normal compact tissue It is this obliteration of the medulla which ultimately leads to the profound anemia and myeloid enlargement of the liver spleen and lymphatic glands The thorax is unmistakable for the ribs are so opaque that even when the exposure has been sufficient to blacken out all detail of the lung structure, these so effectively shield the sensitive emulsion from rays that fixation leaves little trace of silver behind to give detail of these structures on the film. The rib cartilages are not affected so that the bones appear to cease abruptly anteriorly

The vertebral bodies may show three zones, an upper and lower dense zone with an intermediate zone of almost normal density indicating that the changes have occurred by accretion of new bone from the growing cartilage The skull may at this stage be so dense that little detail of its architecture can be made out The radiograph may resemble that of a porcelain skull, so lacking is it in the delicate and intricate detail, or even the coarse detail of the normal skull. In those cases in which the changes are not so advanced the bony prominences, such as the clinoid processes will be seen to be markedly thickened and increased in density and the foramina diminished in size. It is this narrowing of the foramina which is responsible for the cranial nerve lesions and pressure signs that subsequently develop and dominate the clinical picture

In the young infant these changes may not be so far advanced and the radiographic appearances will depend upon the gravity of the lesion and the age at which the changes began to develop The earliest change to be detected in those cases where the abnormal process does not commence until the child is born, is a zone of dense bone at the growing extremity of the diaphysis as in Fig 81 No other deformity of the bony outline can

have been recorded in patients who are absorbing lead or phosphorus. No more interesting radiographs in this connection are to be found than in the papers by *Kemkes* and later by *Gottesleben*. Their radiographs show multiple dense transverse accretions to all the bones from the growing cartilages, but they are not so closely packed together as in the typical *Albers-Schönberg's* disease. They illustrate the planes of bone growth as graphically as the skeletons of animals which have been subjected to intermittent madder feeding. From the distribution of these lines *Gottesleben* deduces that growth is irregular, greatest in the summer, least in the winter, greater in spring than in the autumn. These lines developed in patients who had been subjected to intermittent phosphorus medication.

Radiographs of cases of fluorosis, osteomyelosclerosis, old osteomyelitis, Paget's disease (Osteitis deformans) and osteosclerotic carcinomatous metastases which are associated with increased density and opacity of the affected bones have been interpreted as showing *Albers-Schönberg's* disease, but the appearances of these conditions are distinctive and would not be confused with *Albers-Schönberg's* disease by the experienced radiologist.

Fluorosis of Bone. Soon after the publication of the findings of *P. Flemming Møller* and *S. I. Gudjonsson* it was acclaimed that *Albers-Schönberg's* disease was a much more common disease than hitherto had been thought and that it was due to the absorption, from inhalation or ingestion, of fluorine. Reports soon followed of other cases of so-called fluorosis of bone but the radiographic illustrations showed that these authors also had not appreciated the radiographic characteristics of bone fluorosis for examples of typical *Paget's* disease and secondary prostatic carcinomatous were used.

In fluorosis of bone the first signs are more apparent in the lumbar spine and pelvis. The trabeculæ appear to be rather coarse and less well-defined than normal; gradually an ill-defined increase in the density occurs. Where the detail can be more closely studied, as in the ribs and sternum, this increase in density appears to be due to denser and coarser trabeculæ. The periphery of the bones lose their sharpness of outline. In the well-developed case the bone is much denser than normal, the outlines of the trabeculæ are obliterated. The appearances suggest that some dense granular material had been deposited on them until the interstices of the cancellous tissue were filled. At the site of muscle insertions irregular spicular bony deposits appear to be growing out from the periosteal margins, this will be best seen on the pelvis, the ribs and the bones of the forearm and leg. The vertebral bodies show in addition to an increased density marked lipping of their bodies, but the disc spaces are not decreased. The lipping of the lumbar bodies may not be associated with any change in the curvature and is relatively equal on both sides. The increased density and the marginal deposits tend to give the bone a somewhat more massive appearance than normal. Unusual ossification of some of the ligaments occurs. The changes are generalised and not associated with any destructive process. The bones do not present the abnormal clubbing with the linear transverse or subperiosteal dense accretions, the increased fragility or great density and thickness of the skull which characterise *Albers-Schönberg's* disease. Neither does the latter show the irregular periosteal spicule development at the muscle insertions such as are seen in fluorosis.

The teeth of patients who have absorbed undue amounts of fluorine show chalky white patches in the enamel and brownish or black pigmentation.

Kaj Roholm has written a comprehensive clinical hygienic study on Fluorine Intoxication which is well illustrated and should be consulted by all students.

Osteomyelosclerosis. In certain cases of anæmia, aleukæmic leukæmia and leukæmia the bones develop an unusual density which can be recognised radiographically. Some

W. U. Clifton, et al., recorded the dystrophy in a child at birth when the bones were abnormally dense. The density increased. There was no sign of cancellous tissue. Multiple transverse lines were associated with clubbing of the extremities of the long bones. The child was regarded as *blind at the age of 6 months. The blood appeared* to be normal at the age of 5 years.

Additional Changes. The question arises as to whether the diseases of childhood, such as rickets, scurvy, etc., affect these bones, as in osteogenesis imperfecta, and from a study of the radiographs of reported cases I am confident that they do.

In the illustrations of the case recorded by *Parsons* the extremities of the diaphyses are cupped and there is a zone of semi translucent osteoid tissue representing the expanded metaphyses and the periphery of the bones of the carpus and tarsus.

In the illustrations of the case recorded by *Schulze* a wide zone of translucent osteoid tissue is shown at the metaphyses resembling those seen in renal rickets. That this is osteoid tissue and not the normal bone undergoing the dense calcification can be inferred from the histology. Distinct from the histology of the otherwise apparently healthy marble bone patients from whom bone has been removed at operation, this bone from the post mortem room showed much osteoid tissue.

In the case described by *Verco* Molly W., aged 2½ years, radiographs show dense bones with a zone of "osteoid" in the shafts of all the long bones, suggesting severe additional disease during the first 6 months of life. At about 6 months the baby had gastroenteritis, splenomegaly, severe secondary anaemia and increased fragility of the red blood cells.

The case described by *R. Lightwood* and *E. Rohan Williams* was a male child of 2 years. He showed zones of osteoid tissue at the ends of the diaphyses which had persisted with deposition of dystrophic bone later—showing the vertical splits I had previously recorded. At the age of 6 months the patient showed hypotonia, enlarged epiphyses, a rosary, Harrison's sulcus, an enlarged skull with wide fontanelles and was regarded as rachitic.

With a number of the cases presenting these complications the dystrophy remained unrecognised until a later date. Further, in the case of *Schulze* though the metaphyses were much thickened and devoid of the dense calcium shown in the diaphyses and epiphyses, calcium in abundance was found at post mortem in the kidneys, lungs, vessel walls and ligaments. In this respect it resembles the case of osteogenesis imperfecta, reported by *Johansson*. These are not changes seen in the uncomplicated case of *Albers Schönberg's* disease.

I am of the opinion that they are due to a grave metabolic disturbance possibly in some cases set up by secondary sclerotic changes in the kidneys *i.e.*, *secondary rickets.*

Unfortunately no opinion is expressed on the significance of these changes by the respective writers. Biochemistry and Histology have not helped us in the diagnosis of these lesions. The blood picture and chemical constituents and cellular construction may *show little or no departure from the normal in the well-developed case.* Increase in the calcium content of the blood with normal calcium content of the urine has been recorded. In other cases normal blood calcium is recorded.

Differential Diagnosis. There is no disease other than this which gives the typical radiographic appearances I have described in the adolescent. In the young infant in whom the changes are just beginning to develop, however, the dense zones at the diaphyseal extremities may be simulated in some cretins on irregular thyroid administration, as in the case described by *Goetsky* and *Wehe*. It will be seen from Fig. 203 that the accretions of dense bone which are laid down in some cases of hypothyroidism are associated with clubbing of the extremities of the diaphyses. Somewhat similar appearances

of the long bones. This is well shown in the radiographs of cases of osteogenesis imperfecta tarda, a condition of which these radiographs are more suggestive. In cases of old-standing osteomyelitis and septic arthritis a similar distribution of condensed bone is found, but as in these cases the sclerosed bone is not expanded rather does it suggest contraction, as will be seen from the accompanying radiographs The clubbing of the extremities is not a characteristic feature of the infantile *Albers-Schönberg's* disease, but it is frequently seen in the less severe types of osteogenesis imperfecta and in hypothyroidism, both of which conditions are often associated with the familiar distribution, clinical signs and radiographic appearance of the skull of these two cases. Further radiographs in 1038 do not present the characters of *Albers-Schönberg's* disease No more remarkable case showing club-like expansion of the diaphyseal extremities without osteosclerosis can be seen than that illustrated by *Pyle* The radiographs of an infant a few days old were sent to the author by H B Padwick. These showed universal expansion of the diaphyseal extremities The metaphyseal borders were densely sclerosed, as were the upper and lower borders of the vertebræ The lack of pruning suggested generalised diaphyseal aclasis—unassociated with any suggestion of exostoses The dystrophy was profound and the infant died within a few days (see Fig 15)

Further illustrations and details of cases of this dystrophy with analyses of the cases published, are to be found in the papers by *Albers-Schönberg, Ellinger Karshner*[1] *Kopylow Merrill*, and *Schinz*.

OSTEOPOIKILIE (see Figs. 316 A and B)

In 1915 *Albers-Schönberg* described a further abnormality in ossification which presents a characteristic radiographic appearance

The condition is described under the names osteopoikilie, osteopathia condensans disseminata, and *Albers-Schönberg's* disease.

The radiographs show bones of normal size and shape, but containing in the cancellous tissue multiple ovoid or rounded islands of compact bone. These are best seen on a film of the pelvis (see Fig 316 A) but the extremities of all the long bones show these compact islands. This condition has been reported as a familial affection in association with dermatofibrosis lenticularis disseminata by *Windholz, Buschke* and *Ollendorf*

Schmorl published the radiographs of a boy of 16 years who died of amyloid disease and pyelonephrosis following multiple outbreaks of osteomyelitis, whose bones showed these opaque islands

The clinical history of some cases suggests that the bone condition is related to old inflammatory changes. Thus *E Freedman* described a coloured male, aged 16 who developed endocarditis and pericarditis following an attack of sore throat with multiple migratory joint pains. Fluid from the pericardium contained pneumococci. At the age of 21 he came back to hospital complaining of pain in the back and left knee. A radiograph at this time showed rounded areas of increased density somewhat resembling the early metastases of prostate carcinoma. Three years after he had more pain in the head and his condition was diagnosed as spontaneous subarachnoid haemorrhage. While in hospital he had severe pain in both wrists Systolic and diastolic murmurs were heard. Blood, calcium and phosphorus estimates were normal. At 28 years of age he complained of pain in the neck. Histological section showed granulomatous infiltration of bone. The rounded areas of dense bone coalesced in 6 years and the vertebræ, pelvis, femora and humeri became universally dense Blood appeared to be normal.

S Kadinka and *A Hirleman* found osteopoikilie in a father and his two children who had congenital syphilis.

cases in which the anæmia was preceded by a polycythæmia also appear to show these bone changes. The cancellous pattern of the medullary tissue of the general osseous system appears to be generally obliterated by the deposition of calcium which makes the bones unusually hard dense and heavy Because such changes are general and unassociated with any change in the outward form of the bone or relative proportions of compact and cancellous tissue the radiographic features are not usually as striking as one would expect from the macerated bone Closer inspection of the radiographs, particularly of the cancellous pattern of the upper femora in comparison with radiographs *of similar areas of normal persons will enable the observer to detect the changes.* When they are marked the radiographic appearances are characteristic. It is a condition about which little has been written, and only a few cases have been diagnosed during life

G A. Landoff has given us a good account of one of them.

A woman of 57 years, whose menopause was at 46 and who previously had been always healthy began to complain of pain in the legs hip and back—chiefly at night. No temperature During the last two months she had had cystitis and had become tired and listless—she had a white blood count of 23 000 Later she developed pyelitis and hæmaturia Petechial hæmorrhages appeared The liver was enlarged but there was no enlargement of the spleen or lymph glands. On radiographic examination of the liver the abnormal appearance of the spine and ribs was noted and further radiographs of the skeleton were made The bones of the trunk and of the extremities showed what appears to be a characteristic generalised change all the fine cancellous trabeculæ were wholly replaced by a much coarser and denser structure giving the appearance of a dense stippling rather than a cancellous pattern : this is particularly well seen in the upper ends of the femora, in the borders of the acetabulum, and to a lesser extent in the vertebral bodies and skull *Landoff* gives an account of the cases of anæmia etc. which have been recorded as showing osteosclerosis It was found that the histological coincided with the radiographic appearances The former consisted of more or less medullary fibrosis accompanied by the apposition of new metaplastic bone on the old spongy trabeculæ. Agglomerations of eosinophil cells were observed in the fibrous medulla

The deposition of this new densely calcified bone which produces an increased density of the bones and some obliteration of the normal cancellous spaces, is not associated with the ossification of muscular and tendinous insertions seen in fluorosis, but its clinical features are of a graver character

M L. Sussman has given an illustrated account of 9 cases.

Atypical Cases. *Wakeley's* case In this patient none of the clinical signs accompanying the well-developed case of *Albers-Schönberg's* are recorded The biochemical tests were quite negative. None of the radiographs show the typical distribution or shape of the dense bone in fact the bones are quite normal in shape The distribution of dense bone in this case suggests vascular disturbance for one sees similar effects in bones as a result of chronic sepsis in their neighbourhood There is no suggestion that the dense bone has been laid down as such at the metaphyses as is the case in true marble bones.

Ellis's two cases were the children of parents who are second cousins and they presented similar facial characteristics, eye changes and radiographic appearances. In the latter aspect they do not resemble the typical radiographic appearances of *Albers Schönberg's* disease The dense bone is in the middle of the shafts of the diaphyses and not at the growing extremities. No case of *Albers-Schönberg's* disease has been described in which the radiographs showed the deposition of new normal cancellous bone but in a number of conditions calcium is stored in the middle third of the diaphyses

also in all the long bones of the hands and feet. The fingers show a characteristic deviation between the middle and ring fingers

The long bones show a greater development of the tuberosities and an increase in the thickening of the cortex of the shafts—a feature one would expect to find in individuals possessing the strength and weight-bearing capacity of the achondroplasic.

The latter feature is suggested by the radiograph of a boy 2 years of age (see Fig 274)

The tibia is usually shorter than the fibula The pelvic bones appear to be broader and stronger than the normal, but the true pelvis appears to be generally contracted. The vertebral bodies may be compressed and there is a marked lumbo-dorsal kyphosis which may be evident in the fœtus and be very marked in the infant (see Fig 839), but, as in *Graham's* achondroplastic dwarf skeleton in the Anatomical Department of the University of Birmingham, the vertebræ may not show any marked departure from the normal beyond a little broadening

The bones at the base of the skull fuse prematurely and this results in a compensating expansion of the squamous elements. These factors produce the typical facial characteristics of the condition In some cases hydrocephalus is present (see Fig 431) This is usually associated with transitional occipito-cervical vertebræ which tend to occlude the foramen magnum (see Platybasia, pp 478–9).

In the case described by *Hektoens* the large cranial vault was made up of 172 Wormian bones.

The condition frequently shows a familial distribution Owing to the contracted pelvis, Cæsarean section is necessary

Donald Hunter has described and illustrated achondroplasia in three generations.

It has been suggested that the condition may develop after birth, but the radiographic appearance of the bones negatives this possibility The suggestion probably emanates from observations of cases of chondro-osteo-dystrophy

Interesting cases have been described by *Lawford Knaggs* [1] and *Mex.*

Radiographs are also published by *Looser*

The author [14] has recorded the details of an interesting atypical achondroplasic family Mrs. H., aged 34 and Mr H., aged 37 both of small stature but showing no deformity except smallness of limbs No abnormality was present in either family neither was there any history of illness of parents or of trouble at confinements.

Eight children :—

George William. 14 No deformity
John 12. No deformity
Kathleen. Died when 1-9/12. Short arms and legs.
Joshua. 7 Short arms and legs. See radiographs.
Leslie 5. No deformity
Joseph. Died when 6 weeks old. Short arms and legs.
Dorothy Died when 1 month old. No abnormality noticed.
Ellen. 6 months. Short arms and legs. See radiographs.

Radiographs of Ellen and Joshua.

Skull No definite departure from the normal.
Spine No definite departure from the normal.
Upper Extremities. Scapulæ and clavicles apparently normal.
Humeri, thickened and shortened.
Ulnæ, less than half normal length and thicker than normal.
Radii. Nearly half as long again as ulna. Markedly bowed and thickened. Dislocation of head of radius.

Carpus and metacarpus and phalanges. No definite departure from the normal.

In one case sent to me by *F P Montgomery* and another by *W Davidson* the dense islands were not only isolated ovoid areas but linear streaks of density running in the long axis of the bones, presenting a somewhat similar appearance to what is seen in some cases of Melorheostosis, but without its periosteal bossing (see Fig 318 B). A similar case was illustrated by *L. D Baker* and *H A Jones*

Dense irregular patches in the cancellous tissue are seen in some cases of osteogenesis imperfecta.

In its multiple form it is a relatively rare condition, but isolated islands of compact bone are not infrequently found in the bones of the extremities They can be distinguished by the fact that their long axes are in the plane of the main cancellous trabeculæ

Examples have also been published by *Haack* and *Newcomet*

Voorhoeve published illustrations and details of a case in which the radiographs show dense lines of condensation which run parallel to the longitudinal trabeculæ of the long bones. They are best shown on the lateral radiograph, and appear to be largely confined to the posterior border of the shafts. He expresses the opinion that this condition and osteopoikilie are two phases of one and the same process, and that both should be classified among the dyschondroplasia group

Benton expressed the opinion that as these lines follow the arterial distribution to the bones, the condition might be due to some disturbance of the blood supply

Details and radiographs of an unusual case were published by *Pyle* The patient was a boy aged 5 years, who had had no previous illness but was taken to the doctor because of knock knee Radiographs of the long bones show club-like expansion of the extremities but no increase in the density He suggests that in this case there has been a failure in the primary modelling and pruning of the shafts There is a tendency for the long bones to assume this shape in **Osteogenesis Imperfecta, Albers-Schönberg's Disease, and Cranio-cleido-dysostosis**, but they become modified with age owing to pressure from weight bearing

ACHONDROPLASIA (*Parrot*) CHONDRO-DYSTROPHIA FŒTALIS (*Kauffman*)

(see Figs. 4 274 339)

Lawford Knaggs [3] defines achondroplasia as a defective evolution of the process of endochondral ossification which is in evidence at a very early period of intrauterine life. The dystrophy may be so severe that the fœtus dies (see Fig 4).

Radiographic Appearances. The radiographic appearances suggest that the factor whatever it is, producing the growth disturbance must have ceased to act before ossification began. Osseous dystrophies, such as **Osteogenesis Imperfecta, Albers-Schönberg's Disease** and even **Hypothyroidism**, lead to a characteristic change in the shape of the diaphyses of the long bones, which can be recognised on the radiographs of the newly born child, but in the achondroplasic infant the long bones are stunted only The osseous nuclei for the epiphyses appear about the same ages as the normal they are regular in contour and internal structure and ossification at the metaphyses may proceed with the normal regularity In some cases delay in ossification occurs.

In **Chondro-osteo-dystrophy** which may also produce a dwarf skeleton, marked irregularities in ossification can be demonstrated at the metaphysis, but in achondroplasia after birth there is no evidence of departure from the normal. One might say that whereas in achondroplasia there is an error in the Architect s plans, in chondro-osteo-dystrophy the defects in stature are due to defective building material.

The long bones in achondroplasia are thicker and shorter than the normal. These features may be particularly noticeable in the femora and humeri but they are evident

seen before—the case described by *Silverskiold* in 1926 as a "forme fruste" type of chondrodystrophy bearing the nearest resemblance.

Full details of the case with photographs and radiographs of the entire skeleton, were published the following year.[11]

In the same year *Morquio* published details of a similar dystrophy.

Grudzinski[1] published an account of a new disease analogous to chondrodystrophy in 1928, and the radiographs of his case also show a rather comparable appearance.

More recently similar cases have been described by *Campbell*,[4] *Dale*,[1] *Ghimus Dickson Wright Barton*,[1] *Wahren Ruggles Engel A V Neale and Hucknall, Meyer and Brennemann D O Browne and C Macdonald* and *I S Hirsch*.

Under the term "Gargoylism," *R W B Ellis et al.*, describes an osseous dystrophy associated with corneal opacities, hepato-splenomegaly and mental deficiency. *E A Cockayne* has recorded in a girl of 4½ years hepato-splenomegaly associated with mental deficiency and bone changes. The hair was thick and coarse and dry; the features heavy; bilateral corneal opacities, profuse purulent nasal discharge, enlarged liver and spleen. Teeth imperfectly calcified. Marked kyphosis with slight scoliosis, limitation of extension of limbs. Clenoid and acetabulum shallow. Large sella turcica. Bone changes show some resemblance to chondro-osteo-dystrophy.

Helmholz and *Harrington* called attention to a syndrome characterised by congenital clouding of the cornea, scapho-cephalic head, kyphosis, limited extension of the joints of the extremities and other anomalies. *R W B Ellis* and *S van Creveld* have described a syndrome characterised by ectodermal dysplasia, polydactyly, chondro-dysplasia and congenital morbus cordis.

Radiographic Appearance. Distinct from the dystrophies to which I have already referred this dystrophy attracts attention to the radiographs because of the irregular growth of the epiphyses, though primary and secondary ossific centres are involved in the process. All the primary ossifications may show irregularity of their growing extremities. This irregularity may be most striking in the bodies of the vertebræ particularly in the dorso-lumbar and cervico-dorsal areas where the defective development of the articular processes may lead to displacement, with kyphotic deformity as shown in the radiograph of the spine of W T B (see Fig 377). The abnormal dorso-lumbar kyphos is similar to that which characterises achondroplasia but in chondro-osteo-dystrophy it is masked by the irregular forms of the vertebral bodies. These may appear to be unequal in size, shape and position, the middle third of the anterior surface projecting forward as a tongue beyond the upper and lower thirds, the superior and inferior angles of the vertebral body having an irregular margin.

During adolescence the epiphyses for the superior and inferior surfaces of the vertebral bodies begin to appear as multiple ill-defined ossific nuclei in the spaces above and below the projecting tongues of the middle thirds of the anterior surfaces. The vertebral bodies are compressed and deformed by the superincumbent weight on the disorganised bone, particularly in the dorso-lumbar and cervico-dorsal areas, hence the deformities noted at the clinical examination. This compression of the trunk continued to progress in W T B, in spite of constantly wearing a metal back support, but his appearance was not so grotesque as one has seen in untreated cases. In the infant all the articular cartilages appear to be markedly thickened, for the space between the bony contours is much increased. The extremities of the diaphyses are irregular and the ossific nuclei for the epiphyses first appear as multiple anomalous islands of bone on the other side of the thickened metaphyses. These nuclei gradually fuse, but in those joints subjected to pressure the incapability of the disorganised bone to withstand the normal stresses and strains leads to distortion and compression of the involved bone

Lower Extremities Pelvis normal. Femora irregularity of proximal extremity of neck. No definite changes in shaft

Tibiae. Only about half length of normal and much thicker

Fibulae. Small and diminutive Only about half length of tibia.

Tarsus, metatarsus and phalanges. No definite departure from the normal.

Comments. The ossification of the epiphyses is regular and within the normal limits of time as in Achondroplasia

The chief bony changes are shown in the forearms and legs, but the humeri also show marked shortening and thickening, while the femora show little change beyond the irregularity of ossification of proximal extremity of the neck.

No bone change to be seen in the scapulae, clavicles or pelvis, or in the distal bones of wrist ankles, hands or feet. Differs from true achondroplasia in that there are no changes in skull or face: irregular distribution of the short bones: short fibulae

In a paper on the aetiology and pathogenesis of achondroplasia *Glaume* gives details of an achondroplastic child of 30 months, which gave a positive Wassermann reaction, as did both the parents.

N C *Tanner* recorded dwarfism associated with chronic regional enteritis in a Jewish youth aged 18½ who appeared to be about 14 He grew 2¼ inches in 6 months following the resection of the affected gut

CHONDRO-OSTEO-DYSTROPHY (see Figs. 38, 39 40 150 201 272 273 377)

This was the name given by the author in 1928 to a dystrophy which is characterised by defective development of the skeletal tissues. Many degrees of the dystrophy exist. Some are so slight that they may escape attention, others resulting in stunted growth of the trunk or limbs. Examinations of some of the skeletons of still-births reveal what appear to be profound degrees of the dystrophy apparently incompatible with life. Severe degrees of the dystrophy develop in infants which in the first few months or even years of life appeared quite normal in appearance and size. Attention is drawn to the condition by the development of a kyphos and the appearance of a collapse of the middle third of the trunk with undue prominence of the lower thorax an appearance which may be mistaken for caries of the spine. The child develops a short thick trunk, but the limbs, being of normal length in contra-distinction with the limbs in achondroplasia, appear to be proportionately long Similar collapse of the lower cervical and upper dorsal area may shorten the neck, and the head which has developed normally appears to rest between the shoulders. The joints of the limbs are swollen and may arouse the suspicion of rickets Yet with all this the infant s face may appear to be normal and intelligent (see Fig 471) Growth may cease after the age of 8 years and even though the child may live to the age of 14 years the measurements are little altered The infant becomes an obvious and characteristic dwarf Progressive enfeeblement of the musculature occurs in association with defective developments of the skeleton, the child s activities gradually diminish, its form becomes grotesque and death ensues within a few years—at the age of 14 in the author's original case

In this condition the radiographs show large gaps between the bony extremities at the joints and multiple irregular osseous nuclei in the epiphyses and extremities of the diaphyses, and later pressure deformities of these areas. These appearances indicate degenerative changes in the cartilage and defective ossification. The active stage of the dystrophy appears to cease as the time for fusion of the epiphyses and diaphyses approaches, but the pressure deformities remain as evidence that the dystrophy has existed. If the dystrophy has not been of a severe degree when the active phase has passed, the appearances of the skeleton might be mistaken for those of achondroplasia.

In 1928 at the Royal Society of Medicine, the author showed a series of radiographs of a child which presented very unusual osseous changes the like of which he had not

without supports and walks with a normal gait, but readily gets tired and then lies down assumes the hand on knee position during his sleep. His joints are all enlarged ; there is evidence of wasting The neck is short and thick and he has double inguinal herniæ.

All his teeth show marked caries.

He had pneumonia when 20 months old, but since then, has had no other illness. He a good appetite and for nearly 3 years has been given daily doses of cod liver oil. The parer who are normal in stature and appearance have had one other child (a girl) previously appeared to be quite normal, but died of pneumonia at the age of 21 months. No history any deformity in any member of the parents families could be obtained.

The Radiographic Appearances of the Skeleton. The most noticeable features are the la joint spaces ; the irregularity and multiplicity of the osseous nuclei for all the epiphy particularly of the metacarpals and metatarsals ; the irregular shape and size of the vertel bodies and the dislocation of the vertebræ in the lumbo-dorsal region the shortened thickened long bones and the coarse irregular reticulation of the cancellous tissue and absence of the regular lines of the lamellæ.

For the purpose of comparison I have charted the features of individual bones this case with a description taken from an average of a number of boys at this age per (Table I below)

A further complete radiographic examination of the skeleton was made 4 ye after the original radiographs were taken. These radiographs showed fusion of many the osseous nuclei for the epiphyses. The child had grown only 1 inch in height in 4 years. He showed no response to prolonged thyroid medication. On 20/10 (13½ years of age) he measured 2 feet 11 inches and weighed 2 st. 3½ lb During the n year he steadily declined and was unable to walk. His musculature was flac and atrophied He was pallid and during the next few weeks he began to have " turn during which he became blue and had profuse sweating from a cold skin.

Radiographs in 1930 showed no increase in the length of the limbs or trunk. T long bones were thicker but the pressure deformities at the ends were more mark The multiple nuclei for the epiphyses at the knee had fused but most of the other la epiphyses still showed multiple nuclei. The vertebræ were compressed and very irregu in outline. None of the carpal or tarsal bones presented a normal appearance, nearest being the os magnum. All the bones showed osteoporosis—none showed norr cancellous tissue All the joints appeared to be swollen and the spaces very wide. I height had diminished to 2 feet 0 inches and he now presented a very dwarfed a grotesque appearance. He died in October 1940

Almost identical radiographic and clinical features were shown in a girl, aged Her mother (aged 14 at the time of her birth) and her father were sister a brother This child was sent for to have a periodical review of her condition in Februa 1945 The mother replied with a letter (which not only tells of the feeble state of a ch with this dystrophy but appeals to the author as a human document worthy of reco as follows :—

February 12th, 1945

" Dear Sister —You will be sorry to hear that little Joy (aged 10 years) passed aw January 24th, 1944 The end came sudden, she just went outside and the wind caug her breath and she was gone. We miss her terribly but God was good as I feel n nothing could be done for her

Stimulated by the interest in this case (W T B.) a number of cases have n been collected by the author which show somewhat similar radiographic appearanc These cases have been separated into four groups.

Group A. Consists of cases showing similar clinical and radiographic appearan to the case (W T B) described at 8 years 9 months.

As one would expect, the most conspicuous changes are often to be seen in the hip joints.

Differential Diagnosis. The appearance in an infant of a kyphos which appears to be accentuated with age will suggest to the clinician the possibility of tuberculous caries of the spine, a diagnosis which cannot be put aside until the nature of the bone change has been determined by an X ray examination In some cases they may call for radiographs of the whole skeleton Unless the appearances are typical it would be advisable to watch the progress of the lesion by radiographs taken at intervals of 3 6 or 12 months according to the rapidity of the changes taking place. Multiple ossific nuclei in the developing epiphyses may also be seen in cases of Hypothyroidism, and this may also be associated with stunted development. The condition referred to as Osteochondritis, which is a non tuberculous localised rarefying destructive process, has associated radiographic appearances of fragmentation of the affected bone, consequently a number of cases of this type of dystrophy have been described as cases presenting multiple foci of osteochondritis. The swollen joints may suggest rickets.

The following account of the author's published original case furnishes details of the clinical and radiographic appearances.

The patient, a boy (W T B) aged 3 years 9 months, was a full term child and appeared to be normal until he was 5 months old, at which time the mother detected a small kyphos in

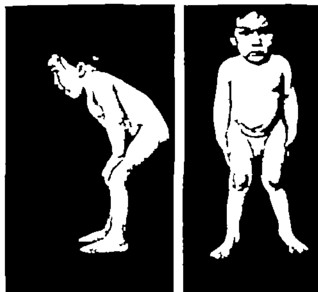


FIG 471 W B. aged 8½ Original case of chondro-osteo-dystrophy Note curvature of spine and position of feet when standing

the dorso-lumbar area. He began to walk at 13 months of age The mother then noticed that the child could not stand erect, but stood and walked with the body supported by the hands on the knees (see Fig 471).

On this account he was taken to the hospital but no definite abnormality was detected Some months later he was examined at another institution and was provided with a posterior spinal support. Similar appliances have been worn continuously since

Condition in 1935. At 10 years of age the boy is a bright, intelligent little fellow and looks relatively well-nourished, but the mother says that he has lost 1 lb. during the past 3 months. He is – feet 9 inches in height and weighs 28 lb 11 oz. He can stand almost erect

TABLE I—*continued*

Area	Normal	Chondro-osteo-dystrophy
Carpus (Fig 238).	Os magnum and unciform *beginning to assume characteristic* features Outline smooth and regular	Os magnum unciform, cuneiform and *semilunar nuclei smaller in size than* normal. No definite shape irregular in outline
Carpal space		Wider than normal
Metacarpals	Proximal extremities rounded with tendency to assume characteristic features.	Proximal extremities of 2, 3 4 5 irregularly conical Shafts very coarse with irregular reticulation of cancellous tissue very thin compact tissue Thicker and shorter than normal
Phalanges.	*Regular convexity of distal* extremities.	*Distal* extremities conical in shape Shorter and thicker than normal. In one patient aged 17 the terminal phalanges now show marked erosion
Pelvis (Fig 277).	Inner margin of pelvis and symphysis pubis "champagne glass" shaped, being about 3½ inches wide at the top and 1⅞ inches deep.	Inner margin of pelvis and symphysis pubis wine glass" shaped, being about 2¼ inches wide at the top and 2 inches deep
Joint spaces.		
Hip.	¼ inch between "articular" surfaces.	⅛ inch between "articular" surfaces
Sacroiliac Joints.	¼ inch between lateral border of sacrum and medial border of ilium	1/16 inch between the borders.
Symphysis pubis.	¼ inch between bony points.	⅛ inch between bony points.
Bone Structure	Fine reticulation borders regular and well-defined.	Coarse reticulation borders irregular Less radio-opaque Relative sclerosis of joint boundaries.
Sacrum.	Regular Joint lines well defined.	Irregular joint lines and spaces irregular and wider
Femur (Capital Epiphysis).	Regular in outline and density Joint surface; regular convexity	Small irregular and fragmented with marked irregularity of diaphyseal extremity
Femur Shaft		Shorter and thicker than normal.
Lower Extremity	Uniform in density and regular in outline	Small areas of increased density particularly inner condyle
Knee Joint space.	1/16 inch midline	Periphery denser 1/16 inch midline
Tibia (upper end).	Regular outline; uniform in density	Periphery denser Irregular outline Not uniform in density
Tarsus.	Regular in outline assuming characteristic shape uniform in density Lamellar striation clearly visible and regular	All present but irregular in outline and shape Definite spur on plantar surface of os calcis. Sclerosis of periphery of superior and inferior surfaces of astragalus and os calcis. Coarse reticulation of cancellous tissue No regular disposition of lamellae
Metatarsals.	Rounded regular extremities with tendency of proximal end of 1 2, 3 to assume characteristic shape	Proximal extremities irregular and conical in shape Coarse reticulation of cancellous tissue Epiphysis of first metatarsal irregular and fragmented Epiphyses of other metatarsals very irregular and "fringed" with denser points of ossification. Distal extremity of first metatarsal very irregular
Phalanges		Shorter and thicker than normal no other definite change

TABLE I

COMPARATIVE DESCRIPTION OF RADIOGRAPHS

Area	Normal	Chondro-osteo-dystrophy
Spine (antero-posterior radiographs) (Fig 377).	Bodies of vertebræ oblong in shape with slight convexity of superior and inferior surfaces. Uniform in density fine reticulation of cancellous tissue Transverse processes regular in outline convex lateral extremities. Articulations arranged in two straight lines which gradually diverge from upper dorsal to upper sacral vertebræ Intervertebral spaces regular gradually increasing from upper dorsal to lower lumbar	Bodies irregular in outline and shape Outlines difficult to define particularly in cervical upper three dorsal and all lumbar vertebræ Structure indefinite and mushy Transverse processes irregular in structure and outline with concave lateral extremities. Articulations irregular in alignment and spacing Intervertebral spaces irregular and ill-defined. (In one patient now 17 years, there is marked platyspondylia and an unusual deformity of the bodies)
Spine (lateral radiographs) (Fig 377)	Vertebral bodies Regular in outline and density rectangular in shape with slightly concave anterior borders sometimes with median notch or groove extending towards the posterior surface Spinous processes regular in outline and density with convex posterior extremities	Cervical bodies irregular in outline and density The upper vertebræ are pushed *into the depression in the softened base* Dorsal bodies upper three irregular in outline and "mushy" in appearance The lower dorsal bodies have "tongued" anterior surfaces and are irregular in size The lumbar bodies are irregular in size and shape *There is a forward dislocation of* the dorsal vertebræ on the first lumbar the anterior surface of the body of the first lumbar being on a plane with the posterior border of the twelfth dorsal. The articular processes are small and irregular Spinous processes *short and stunted.*
Skull.	See pp. 1 and 2.	Marked caries of all the teeth Sella turcica normal in size and shape The basilar *impression is elevated by the* upward thrust of the spinal column on the *softened base so that the atlas and axis lie* within the depression and the neck is shortened.
Ribs.		Thicker than normal with expanded heads and anterior extremities.
Humerus (upper end).	Regular in outline epiphysis *assuming characteristic* features.	Three "spotted" rounded centres of *ossification of epiphysis Upper end of diaphysis* thickened and irregular in shape
Shoulder Joint (Glenoid)	Regular joint space	Irregular in outline Considerably wider than normal.
Humerus (shaft).		Thicker and shorter than normal. Compact tissue appears to be thinner than *normal.*
Humerus (lower end)	Regular and uniform in structure	Fragmented appearance of external condyle
Ulna and Radius.		Thicker (particularly upper third) and shorter than normal with *irregularity* of superior and inferior extremities Radial epiphyses irregular

child aged 4 years, show no ossification of the femoral necks or epiphyses, a similar lack of ossification was seen in the older boy on radiographs taken when he was aged 10 years (see Fig 273) No ossification of the femoral head or neck was present in the younger case 10 years after the first examination but the normal position was preserved. The acetabula had developed beyond the normal size but were irregular in outline. The femoral shafts were hypoplastic Four years after this (now aged 14 years) there was still no ossification of the femoral head or neck on either side and the trochanteric area was now considerably elevated higher than the roof of the acetabulum. Bilateral McMurray s trochanteric osteotomy not only failed to lessen the deformity it appeared to accentuate it. The bones of the extremities show very little evidence of the dystrophy—the chief being a separate epiphysis for the base of the second meta carpal

Similar cases have been described by *Morquio Mayer* and *Brennemann*, *Thursfield* and *Lightwood* The histological characters of the disorganised areas in the latter case were investigated by *Harris* and *Russell*, who report a mucoid degeneration of the cartilage.

Group D In this group the disorganisation is confined to the vertebræ No irregularity or growth disturbance can be detected in any other part of the skeleton. As in most of the bone dystrophies, a separate epiphysis for the base of the second metacarpal is present.

Two examples of this type were seen: boys, 10 and 12 years

The vertebral bodies are compressed and irregular the first lumbar body in both cases being only half the size of the others, the anterior half being missing There is a localised kyphosis produced by backward displacement of this vertebra and angulation of the upper and lower columns at this site

In one case of the author s a boy of 14 years, whose skeleton was examined because of the changes in the hands (see Fig 40), there were bilateral short femoral necks with an appearance suggesting osteochondritis dissecans: coarse cancellous bone at knees, flattening of metatarsal heads and irregular ossification of vertebral bodies as in Scheuermann s disease

It will be seen from the foregoing details that the dystrophy may affect the spine only the spine and proximal joints, or the whole skeleton, and that the resulting deformity depends on the severity of the lesions and the pressure to which they are subjected

The more severe types remain as dwarfs, the neck shortened and the occiput kyphosed owing to the moulding of the base of the skull over the upper cervical vertebræ and disturbances of growth at the cervico-dorsal junction; a prominent dorso-lumbar kyphosis in young patients, particularly those showing small defective vertebræ at this level, and a marked lumbar lordosis in older children may be observed. The trunk appears to be compressed, and there is a corresponding broadening and protrusion of the anterior wall of the thorax and abdomen.

The radiographic appearances are distinctive, but if isolated joints only are radiographed, they may be confused with such conditions as cretinism, localised osteochondritis achondroplasia or chondromata. The condition described as chondy strophia calcificans congenita may be mistaken for this dystrophy (see p. 17) The resemblance of some of the radiographs to those of cretins suggests that the condition may be due to a pluriglandular endocrine disturbance. In support of this the following is *interesting*: in one of the author's cases marked irregularity of ossification occurred over a period of 6 months, and then there was a return to normal ossification. The irregular zone remained in the shaft for several months, but eventually disappeared

The author has under observation a family of four children aged 17 14 12 and 2 years. The eldest has developed epilepsy but no definite skeletal deformity The other three have the typical clinical and radiographic features of W T B There was no evidence of consanguinity of parents. The kyphotic deformity of the spine was noticed at birth in the youngest child, but not until after illness following tonsillectomy when 12 months old, in the older child. A further example was seen in a child aged 6 years. Six such cases have been seen by the author during the past 6 years.

The cases published by *Campbell, Dale Neale Hucknall* and *Ruggles* bear a close resemblance to those in this group.

The dystrophy may be of such a severe degree that the foetus dies *in utero*. A radiograph of such a foetus showed several osseous nuclei in each vertebral body The long bones were shortened and thickened and their extremities were irregularly expanded. All the bones of the skeleton, with the exception of the clavicles, showed evidence of defective development.

Group B In this group the active phase of the condition appears to cease before puberty The disorganisation of the metaphyses leads to marked shortening of the limb bones and *pressure deformities of the extremities of the long bones and vertebral bodies.*

Three examples of this moderate generalised form have occurred in my series, all boys, aged 7 9 and 17 years.

The eldest boy (H. J) was radiographed when he was 12 years old. At this time the patella was represented by multiple bony nuclei (see Fig 272) and all the epiphyses including the vertebral showed a similar fragmented appearance. The extremities of the long bones were expanded and irregular the bones of the forearm being markedly shortened owing to the disturbance of growth.

At 17 years of age, radiographs of the patient show fusion of all the bony nuclei to the diaphyses. *The borders of the vertebræ appear to be compressed and broadened. The bones* of the pelvis are broadened and the true pelvis generally contracted.

The acetabula are considerably broadened and flattened to accommodate the expanded femoral heads. The femoral necks are broadened and shortened The great trochanters are as high as the roofs of the acetabula—a bilateral coxa vara. The joint space between each femoral head and acetabulum appears to be a little wider than the normal. The knee joint spaces also appear to be deeper and the intercondyloid space is widened. The bones of the hand are short and stumpy

The radiographs of another boy (C. C.), taken when he was 9½ years of age, show marked changes at the extremities of the long bones and at the lumbo-sacral junction where there is *a marked pressure deformity The sacrum lies in a horizontal place with its upper extremity* directed forward Radiographs taken when he was 14½ years old show that the active phase has passed the disorganised bone has consolidated, but, owing to the disturbance in growth, the long bones (femora, tibiæ fibulæ, humeri radii and ulnæ) appear to be about half or two-thirds the normal length. Their extremities show less marked changes

A further example with a similar appearance was seen in a boy aged 18 Similar appearances are illustrated in a boy aged 14 years, described by *Southam* and *Paterson*

The cases described by *Buxton* (a youth, aged 20), *Ghimus* (boy 9 years), *Pritchard* (boy 8½ years) *Scott* (two sisters, 17 and 21 years) *Turner* (boy 10 years), *Wahren* (boy 17 years) *Wright* (boy 10 years), *D O Brown* and *C Macdonald* (8 cases), present somewhat similar radiographic appearances.

Group C. In this group the changes are chiefly confined to the spine and hip joints, and less frequently to the knee joints.

Examples of this group were seen in two boys, aged 1 year and 10 years In the younger patient the lateral radiographs showed a marked irregularity of the borders of the vertebral bodies, and in the older boy the vertebral bodies are irregular and appear to be compressed, laterally expanded and fragmented, an appearance which simulates *that of a severe osteochondritis. The radiographs of the pelvic region of the younger*

FIBROSIS OF BONE (POLYOSTOTIC FIBROUS DYSPLASIA) (see Figs 63 64 180 181 182 261 317 and 445)

In the second edition of this book I drew attention to an unusual type of osteogenesis imperfecta which I had observed in a patient of 6 over a period of 5 years I recorded that "in this patient, with the exception of the skull, which exhibited marked general hyperostosis, the bones of the skeleton appeared as thin casings having a whorled central structure suggesting cartilaginous metaplasia. All the tubular bones appeared to be expanded, bent and devoid of any suggestion of differentiation into compact and cancellous tissue." *F Braid* who unknown to the author had observed the patient at another hospital, had recorded it as an osseous dystrophy following icterus gravis neonatorum. At that time the child showed little obvious departure from the normal beyond some increase in the dorsal curvature and bending of the sternum and the radiographs showed what was described as a cystic condition of the shafts of all the long bones. *Dr Braid* expressed the opinion "It seems probable that there may be an ultimate spontaneous cure when growth has ceased." Our subsequent radiographs, taken independently showed a progressive development of the bony changes. The expanded bones, the middle one-thirds of the femoral, humeral and tibial shafts in particular suffered fractures and marked bowing The whorled internal structure showed multiple rounded islands suggesting cartilage which had calcified fibrous walls During the past 5 years he has been a complete cripple His lower extremities are grotesque in form and of no use to him. His skull is now at the age of 16 years, nearly 2 inches thick, which makes his head appear abnormally large. His skin is markedly pigmented but in spite of this unfortunate development of his skeleton he remains intelligent and cheerful. If the term osteogenesis imperfecta ought to be applied to any condition apart from that described in the previous chapter it should be this, for it is obvious from examination of the serial radiographs that the osteogenesis of all the bones is imperfect, but there are certain features about this condition which make it desirable to use a different name so as to distinguish it from the condition described under that title The chief being that in this condition the skeleton, as in Ollier's disease, may only show a patchy distribution of the abnormal osseous change some bones on both sides of the skeleton showing extensive changes, others appear normal, as in the case recorded by *D J McCune* and *H Bruch* under the title of "Osteodystrophia Fibrosa. Other cases show unilateral development of the dystrophy which is shared by the skull, jaw and all the bones on the one side, most of the bones on the other side being practically normal as in the case described by *H B Stauffer R A Arbuckle* and *F C Aegerter* The unilateral disposition of the lesions in certain of these cases was well shown in a case of the author's. A girl aged 1? years had menstruated since she was 6 years of age Then her ovaries were explored because of precocious menstruation and pubic hair—material from sections from ovaries reported by the pathologist as a granulosa cell tumour" The ovaries contained multiple follicular cysts but no definite tumour in either Recently she had a spontaneous fracture of the middle third of the left humerus and on complete radiography



FIG. 472. R. W Generalised polyostotic fibrous dysplasia (see Figs. 63 and 180)

The radiographic features of the skeleton of this case were not characteristic. The mother had had a severe toxæmia in the early days of her pregnancy. A familial distribution has been noted in several cases. Three of the author's cases were sisters. 4 out of 5 of *Morquio's* cases were in the same family.

Ruggles records the condition in the eldest, the fourth and the seventh child of a family of seven, and two in another family of three children. *Scott's* [6] cases were sisters. *Snoke's* 2 cases were father and daughter.

In a personal communication *Cockayne* suggested that consanguinity of parents might be the deciding factor. Definite evidence of this was obtained in one of the author's cases (see p. 563); this would appear to be a strong feature in Albers-Schönberg's Disease.

Appearances very closely resembling those of chondro-osteo-dystrophy are seen in some cases of severe chronic polyarthritis of infancy, as in the case illustrated by *Kienbock* [3] and as a complication of infantile smallpox.

An unusual dystrophy which resembled the superficial characters of chondro-osteo-dystrophy but which showed ossification of the epiphyses commencing in dense nuclei and fusion of the epiphyses before the age of 13 (some epiphyses never appeared) was described by the author[31] (see Fig. 21). The patient is a dwarf and the elder sister of a normal brother.

POLYCYSTIC DYSPLASIA OF BONES (Figs. 84 A and B, 95, 170, 214, 227 A)

In the condition to which I give this name multilocular cystic lesions develop in multiple sites with irregular distribution throughout the whole skeleton, more commonly at the extremities of the diaphyses, though the bones of the skull, vertebræ and pelvis may show isolated lesions. All degrees of severity have been seen, the more severe showing extensive lesions in many of the bones of the skeleton, the less severe showing but isolated lesions which may appear to involve only one side of an affected bony extremity or scallop the sub-periosteal surface of its cortex over but a small area. The affected segment is expanded beyond the bounds of the normal. In the young the lesions will be seen in close association with the growth cartilage, i.e., it is a temporary defect in ossification, but as the patient grows the lesions are limited by the development of sound bone; consequently as the latter is laid down the lesion does not increase in size and appears to travel away from the extremity towards the centre of the shaft (see Figs. 84 A and B). It may be discovered accidentally at that site, sometimes because of fracture, and be mistaken for a developing bone tumour or a Brodie's abscess. When the whole diaphyseal extremity is involved, i.e., the whole growth cartilage was disorganised, the possibility of subsequent development of sound bone appears to be remote. The large multilocular areas are incapable of withstanding the stresses of normal function and fractures occur with subsequent deformity. Secondary changes resulting from the formation of callus or infection may mask the nature of the lesion. Segments of bone may be resected and replaced by a bone graft without recurrence. *I. Snapper* has recorded an isolated lesion having these features as a lipoid granuloma, but the position and characters of the lesion indicate that it is of some years' duration. This may account for the microscopic appearances which caused him to so name it. The case of a man of 25 years published by *I. J. Ackermann* as Tuberose Sclerosis had multiple polycystic areas in both ilii and upper femora and partial destruction of a vertebral body. In addition there was polycystic fibrosis of the lungs and the patient suffered from polydypsia, polyuria, pain in the back, chest and both legs. The lesions showed no progression in 6 years. This case is interesting in that it presented features suggesting lipoid granulomatosis but not tuberose sclerosis.

Some remain in a rudimentary form, while in others the growth is rapid and huge irregular bones develop. The peripheral outlines of these exostoses is usually well defined the internal structure shows a cancellous trabeculation rather coarser than the normal bone In the larger specimens, which may now be described as osteochondromata, the cancellous structure is often very coarse or cystic in appearance The periphery may be more or less regular in outline, or may show projecting branches or tubercles, the extremities of which may be dense and sclerosed, as in Figs 110 and 202, or show marked irregularity indicating chondromatous proliferation. The base of the exostosis blends with the diaphysis, though in some cases the coarseness of the trabeculation indicates the junction They are commonly found at the upper and lower ends of the femora, tibiæ and fibulæ upper ends of the humeri, and lower ends of the radii and ulnæ and on the scapulæ Exostoses, which are usually less conspicuous, may be shown on the ribs, pelvis, and long bones of the hands and feet. In the pelvis they may cause a triangular deformity of the brim Growing from the vertebræ they may compress the cord or nerve roots and produce paralysis, as seen by the author in a case of multiple exostosis. The symptoms disappeared on surgical removal of exostosis.

Keith [1] has suggested that the bones which are formed entirely within cartilage are free from the disorder No exostoses should therefore be found growing from the tarsal or carpal bones, the epiphyses of the long bones, the vertebral bodies or sternum, but occasional exceptions to this are found

Epiphyseal and diaphyseal growth may be checked or distorted by neighbouring diaphyseal exostoses, consequently asymmetrical bone growth may result in marked deformity This is particularly to be noted in the forearm or leg where, as the result of exostoses on one bone, unequal growth occurs, resulting in dislocations at the elbow or wrist joint, and bending and sometimes pressure absorption of one or both bones. Further the size of the exostoses may restrict the movements at the neighbouring joint or cause damage by pressure on adjacent structures Trauma may cause rapid growth, suggesting sarcoma.

Popliteal aneurysm has been reported from this cause (see Fig 211 and p. 215)

In a small percentage of cases the tumours undergo **sarcomatous changes** but cure has resulted from localised resection as in the case recorded by *Fennel* in a man of 45 years. There was no recurrence in 13 years *Ehrenfried* estimates this metaplasia to be as high as 5 per cent. Rapid increase in the size of the tumour after the epiphyses have fused should be viewed with great suspicion.

It must be realised that patients with this dystrophy may develop the additional signs of tuberculous syphilis, rickets or scurvy which will alter the radiographic appearances accordingly

The condition has been described as multiple cartilaginous exostoses, multiple congenital osteochondromata, hereditary multiple exostoses, hereditary deforming chondrodysplasia, diaphyseal aclasis and dyschondroplasia. Under these terms the two conditions, *i.e.*, multiple exostoses and multiple chondromata, which produce two distinctive radiographic appearances, are described

Hereditary deforming chondrodysplasia is the term applied by *Ehrenfried* to a chondrodystrophy showing a marked hereditary distribution and associated with the development of multiple cartilaginous exostoses which result in deformity and secondary distortion of the limbs. He reviewed 300 published articles containing the details of over 600 cases. He deals with or confuses multiple exostoses and multiple chondromata under the one heading

Direct hereditary transmission can be ascertained in a large percentage of cases thus, *Ehrenfried* found definite evidence of this in 176 cases out of 286, 63 being in ten

of the skeleton typical lesions of this dysplasia were found in the left humerus, radius and ulna, parts of all metacarpals and phalanges of thumb, ring and little fingers (see Fig 64) left ilium, femur fibula (not tibia) the three middle metatarsals and their phalanges No lesions of any size were present in the right side of the skeleton, the skull, spine or ribs.

While in other cases the dysplasia is represented by isolated fibrous expansions of different bones, including the skull, as in the condition which *R C Elmslie* included in his description of "Fibrosis of Bone." *L. Lichtenstein* who gave the condition the name Polyostotic Fibrous Dysplasia, suggested that it was predominantly unilateral, and indicated that the osseous lesions were not of the nature of cysts but due to proliferation of fibrous tissue (in one of my cases also cartilage) of rubbery consistency which caused absorption of the compact cortex and localised expansion of the bone. Within the expanded area which, distinct from the condition to which the term polycystic dysplasia should be confined, has a density little less than normal bone, there is no cancellous tissue. The fibrous expansion has a ground-glass-like appearance When cut into it feels hard and somewhat gritty is of a greyish white fibrous structure in which trabeculæ of osteoid tissue may be distinguished.

The condition, though present, may not be discovered until deformities due to bending, fracture or expansion of the long bones occur or until the prominence of a cranial or facial focus becomes evident (see Fig 261). Only one focus may be recognisable clinically but if the whole skeleton is examined other isolated foci will often be found. Localised foci in the face or skull have been erroneously recorded as examples of leontiasis ossea—a term which should be reserved for the condition described on pp. 498-501

It may be discovered at any age. It is associated with pigmentation of the skin, bleedings, and increased phosphatase. There may be an increase in the serum calcium but no definite change in the serum phosphorus figure. It is not associated with hyperparathyroidism; this is denoted by the fact that all the unaffected bones of the skeleton preserve their density and structure. In addition to the generalised case the author has a number of cases which show varying degrees of the dystrophy In one girl of 12, one of 15 and one of 18 years, the condition was first revealed by spontaneous fracture of the upper one-third of the femoral shaft. In one case a girl of 18 years showed evidence of an old fracture of the upper one third of the femur which had consolidated. In a woman of 46 years radiographs revealed old fractures through expanded fibrous areas in the trochanteric region which had consolidated with coxa vara deformity The appearances of the cases suggest that it occurs more frequently in females and if the expanded areas can be "protected consolidation occurs in early adult life

I Snapper has recorded the case of a girl, aged 10 years who had multiple cyst-like lesions in the femora, tibiæ and humerus with a history of fractures at the age of 7 He records the case as one of lipoid granulomatosis, though neither its radiographic features, as shown in his illustrations nor its clinical features bear any resemblance to that condition. They are however indistinguishable from those of polyostotic fibrous dysplasia. The case is interesting as it developed a rapidly growing sarcoma in one femur at the age of 14 years and died from visceral metastases.

MULTIPLE EXOSTOSES OR DIAPHYSEAL ACLASIS (*Keith*) (see Figs. 41 119 160 202).

The striking feature in this condition is the formation of exostoses near the extremities of the diaphyses of the long bones In the infant, before the appearance of the epiphyses, this dystrophy is indicated on the radiograph by small bony buds or projections from the sides of the diaphyseal extremities. These buds continue to grow until the diaphyses and epiphyses have fused The rate of growth of the exostoses varies.

which have been so transmitted cryptically for a number of generations Because of its sporadic occurrence in a pedigree the inheritance of a recessive abnormality is more difficult to trace than that of a dominant

I have carefully gone into the history of 10 of these cases of multiple chondromata which I have examined and in no case could I obtain any evidence of such hereditary taint. I am indebted to *Dr Connell* and *Dr Mather* who have supplied me with the family details and allowed me to examine the radiographs of two other cases, and in neither of them could they obtain such evidence

Yet the condition is so manifestly a developmental defect that one must assume that it has arisen from mutation in the affected chromosomes even though *Bentzon* makes the interesting claim that he had produced a similar defect in the bones of a rabbit whose sympathetic innervation to the part he had destroyed.

The condition was first described by *Ollier* and is referred to as *Ollier's* dystrophy

He described it as a unilateral dystrophy but it was later discovered that bilateral lesions were present in his case.

Though most of the cases appear clinically as a unilateral deformity only it will be found, by radiography of the skeleton, that the lesions though asymmetrical are generally bilateral.

One of the author's cases merits the title of chondromatosis for radiographs of the entire skeleton show that at all growth centres the dysplasia is manifest, including the vertebral epiphyseal plates, both ends of the ribs, all borders of scapulæ and ilii, the base of the skull. The most extensive deposits are shown in Fig 120

Dr Mather has recently shown me radiographs of a case in which lesions can be detected on one side only All my cases show bilateral lesions, though in some the defects on one side are very slight and but for the complete radiographic examination of the skeleton would have been missed. In some cases the bone changes are associated with multiple hæmangiomata as in the specimens numbered 2161 1–3 in the Museum of the Royal College of Surgeons, London.

Shortening of one or more limbs may be apparent owing to disturbance in growth caused by the chondromata. Dislocation of the head of the radius is not uncommon in those cases when the growth of the ulna has been retarded (see Fig 99) A deformity resembling that produced by pseudarthrosis may occur at the junction of the middle and lower thirds of the tibia owing to chondromata developing within the bone at this site. Shortening of a lower extremity is often due to chondromatous changes in the upper third of the shaft of the femur

In some cases development of the multiple chondromatous masses in the phalanges, metacarpals or metatarsals, carpus or tarsus leads to a hideous deformity of the hands and feet. Some elements may show enchondromata, others cauliflower like outgrowths. The other bones of the skeleton may be normal. In others metaplasia of the chondromatous tissue occurs and the picture is concluded by the rapid development of sarcoma.

Questions will be put from time to time by anxious parents as to treatment of the lesions revealed by the radiograph. As we have seen, the chondromatous lesion may completely destroy the bone or impair its capability of supporting weight. Under these circumstances it is advisable to advise excision of the abnormal tissue from those sites in which the radiographs suggest either that the neighbouring joint surface will be destroyed or a pathological fracture result. The hideous deformity of the hands and feet produced by the chondromata can be prevented by conservative operative measures before the joints are involved—a procedure with which *Naughton Dunn* achieved excellent results.

Radiographic Appearances. These vary in extent and distribution. They are

families while *Reinecke* found such evidence in 172 cases which occurred in thirty-six families and traced the condition back through five generations.

After investigating a number of cases, *Locke* expressed the opinion that transmission is more often through the male.

No skeletal dystrophy shows the affect of hereditary taint more clearly than that of multiple exostoses. It is a dominant character which often pervades every generation of affected families, much to the distress of some of the unsuspecting and unaffected members who are joined by marriage. The dystrophy is transmitted from father or

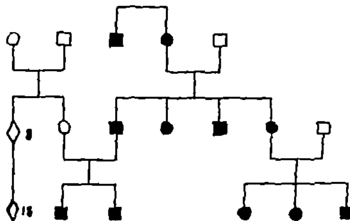


Fig 473 Showing the distribution of multiple exostoses in the S family
○ Female □ Male unaffected.
● ■ Affected Females and Males.

mother to son or daughter as will be seen from the pedigree (Fig 473) of one of the families examined by the author

Numerous workers have recorded evidence of hereditary distribution Cases have been seen in which no evidence of hereditary taint could be found. The condition may be recognised as an accidental finding in infancy by radiography or by the shortness of a limb due to disturbance of bone growth, or the presence of exostoses in the neighbourhood of the large joints, or by the development of sarcomatous changes. Further examples can be seen in the papers by *Burke Ehrenfried*, *Leucutia* and *Price*

MULTIPLE CHONDROMATA (see Figs. 42–45 99 100 120 210)

Though this dysplasia is sometimes included with the former under the headings of Multiple Cartilaginous Exostoses, Hereditary Deforming Chondrodysplasia, Dyschondroplasia, Diaphyseal Aclasis, it presents several very distinctive characters.

Whereas with multiple exostoses a dominant hereditary taint is to be detected in affected families with multiple chondromata evidence of such taint cannot be obtained, though it may exist as a recessive factor the exostoses present on the phalanges and metacarpals do not produce the extreme multiple deformities seen with multiple chondromata and whereas radiographically the multiple exostoses appear as bony projections from the periphery of the affected bones, the multiple chondromata appear as defects or gaps in the ossification of the bones or their peripheries. *Ruggles Gates* has shown that a recessive gene may be transmitted for an indefinite number of generations until it meets the same recessive gene from another individual and as he says, probably the only danger attached to cousin marriages is that they will thus bring together genes

of the cancellous trabeculæ between this and the growing end of the diaphysis. Others show expansion of this diaphyseal extremity by tissue devoid of calcium. This expanded extremity may present a regular outline with peripheral bony striations running in the axis of the phalanx, giving it an onion-like appearance, or it may show a unilateral expansion, having a marked defect in its most prominent bony periphery. With the extension of growth of the chondromatous tissue more and more bone is absorbed. Bony fragments are also broken away and carried in the abnormal tissue beyond the line of the periphery of the involved phalanx and ultimately radiographs show little of the phalanx apart from a few scattered fragments of bone in the exuberant chondromatous tissue.

Changes in the larger bones of the skeleton present somewhat similar appearances and the destructive changes may give rise to a spontaneous fracture. In some cases this is the first indication of the presence of the dysplasia. The abnormal tissue may appear in the shaft of a long bone as a transverse radiotranslucent zone or pseudo-fracture as in the case of C. W. referred to previously. It was the apparent relation of the bony changes to the site of the nutrient foramen and the fan-like distribution of the branches of the artery that caused *Bentzon* to suspect arterial changes as the cause of the development of the chondromata. Working on the assumption that cartilage proliferation occurs at the site of a fracture as the result of increased vascularity he made attempts to damage the sympathetic innervation of the nutrient vessels of experimental animals and in two cases he succeeded in producing changes in the phalanges which simulated those seen in multiple chondromata. *Chrysopathes* supports the theory that the condition is due to increased vascularity but suggests that it might be due to lesions in the crossed and straight pyramidal tracts, as well as the tracts of *Goll* and *Burdach* and the zona radicularis. Considerable variation in the distribution of the lesions is seen in different cases. In some, most of the distal small bones are affected and little attention is attracted to lesions in the long tubular bones. In others, lesions in the latter bring the dystrophy into prominence and the peripheral bones may escape. Rapid growth of one or more of these chondromatous masses associated with blurring of the bony outlines of the part is very suggestive of sarcomatous metaplasia, a sequel which has completed the clinical history of a number of these dystrophies.

Multiple chondromata associated with multiple hæmangiomata were recorded by *Kast* in 1889. The latter are indicated in the radiographs by multiple round phleboliths in the soft tissues.

J. H. Sheldon has recorded and illustrated a case of multiple chondromata in which secondary sarcomatous changes developed, causing the death of the patient.

Schrattenbach has published the details of a similar condition in a man of 47 years.

Illustrations and descriptions of similar interesting cases are to be found in the papers by *Cleveland* and *Cole*.

CRANIO-CLEIDO-DYSOSTOSIS (see Figs. 19. 432. A, and B)

This condition was described by *Barlow* in 1883, but it was *Marie* and *Sainton's* work in 1897 which focussed attention to it. Over 100 cases have been described. Some showing familial hereditary distribution, others not. It may be transmitted by father or mother to son or daughter. Attention may first be attracted to the condition by the patient's ability to fold the shoulders so that they meet in the midline anteriorly. The face may appear small in relation to the cranium. The lesions are usually symptomless and bilateral but not always symmetrical. It was at one time considered to be a defect in the ossification of the membranous bone, and this type of bone formation was suggested in the sites showing lesions. We know that this is not an accurate account

illustrated in Figs. 42–45. In some cases the lesions appear to be confined to the phalanges, metacarpals, metatarsals, carpus and tarsus, all the other bones being normal. These chondromata usually appear as defects in ossification of the growing end of the diaphyses. The nutrient foramen may be enlarged and slit like and from its neighbourhood the diaphyseal extremity expands, sometimes more on one side than the other. Longitudinal strands of bone mark the periphery of an expanded non-osseous tissue giving it an onion like appearance. Growth of the chondromata continues to adolescence or early adult life when the extremities of the lesions, which had appeared irregular because of the unequal ossification, takes on a round form as the result of calcification and later ossification of the capsule, and eventually of the substance of the tumour. In some cases rapid irregular growth leads to localised destruction of the bony casing, pieces of which are carried into the body of the tumour. Another form of chondromata which is seen in the phalanges and metacarpals shows as multiple round islands—enchondromata. These may be found only in one or two fingers and do not produce the hideous tuber-like deformity of the fingers which is seen in the first type.

In another type the radiographs of the infant show longitudinal defects in ossification spreading up the shaft from the metaphysis. In isolated cases the chondromatous tissue produces an appearance resembling a pseudo-fracture—when they occur at the lower end of the tibia angulation may be produced by pressure on the unossified segment. Spontaneous fracture may occur through bones weakened with a zone of cartilaginous tissue. Multiple dense calcium nuclei may later be seen in the defects.

In the most extensive type radiographs of the infant may show marked irregularity of the borders of the flat bones, the scapula and pelvis, with expansion and irregularity in ossification of the diaphyseal extremities from the neighbourhood of the nutrient artery. After 2 or 3 years dense nuclei of calcium are seen in the defects and later these are ossified and become of the same density as the parent bone. In this condition the epiphyses of all the bones including those for the superior and inferior margins of the vertebral bodies show ossification commencing as multiple dense calcium nuclei—these too, eventually ossify, lose some of their density and fuse with the parent bone. Injury to isolated chondromata may result in rapid growth in which the structure of the affected bone may be completely broken up and its fragments carried away into the tumour mass. Localised resection of these tumours usually results in cure but in some cases sarcomatous metaplasia takes place and the patient dies from multiple secondaries.

The dysplasia may not be suspected on clinical examination until an injury to a part necessitates the taking of a radiograph. This was the case in one of the patients sent to me. This patient C. W., aged 6 years, sustained an injury to the hand and a radiograph was taken to ascertain the extent of the bone injury. This revealed the typical appearances of multiple chondromata, and on radiographic examination of the entire skeleton it was found that lesions were present in the phalanges of both hands, being more extensive on the left than on the right, marked defects in the lower third of the left radius and ulna, a pseudo-fracture of the right ulna at the junction of the middle and lower thirds, a pseudo-fracture about ½ inch above the left acetabulum, fan-like striations of the ilium on both sides, defects in the third and fourth left ribs and the fifth right rib, marked defects in the upper half of the left humerus but none in the right, bilateral defects in the lower thirds of the tibiæ, bilateral defects in the proximal phalanges of the feet. No definite abnormality of the skull, spine, scapulæ or femora could be seen. The changes in the bones can best be seen in radiographs of the hand (see Figs. 44 A, and B). The appearances presented in the involved phalanges and metacarpals depend upon the extent of the chondromatous tissue. Some show what appears to be merely an increase in the size and length of the nutrient foramen and absorption

than normal, but they gradually expand to the normal at the extremities. The skull may show an increase in its antero-posterior dimension, but a reduced vertico-occipital dimension. There may be a definite elevation of the basi-occiput.

The two sides of the neural arches may have failed to fuse with each other or with the vertebral body and the notch seen on the lateral radiograph on the anterior surface of the bodies may persist for many years beyond the normal age for fusion.

The epiphyses late in showing ossification, when they do appear frequently exhibit a fragmented appearance. Thus, in the case illustrated in Figs. 264 A and 264 B no ossification of the femoral epiphyses was seen at 3 years of age, but at 10 years of age fragmented epiphyses, having a superficial resemblance to osteochondritis, are seen.

This delay in ossification of the femoral epiphyses may be useful in indicating the nature of the dystrophy. It should not be confused with chondro-osteo-dystrophy (compare Figs. 264 and 273).

The irregular ossification of the epiphyses renders them liable to marked pressure deformity, a good illustration of which can be seen in the paper of *Berard* and *Nocel*. Their radiographs of a patient aged 30 years show extreme deformity of the femoral and, to a lesser extent, of the humeral heads.

Further illustrations will be found in the paper by *Engelbach* and *McMahon*.

In some cases of hypothyroidism which have been subjected to thyroid administration radiographs showed bands of dense bone at the growing extremities of the long bones (see Fig. 203). This feature is well illustrated by radiographs in the paper published by *Goetsky* and *Wehe*. Such an appearance is not seen in all cases of hypothyroidism. Even in severe cretinism, when thyroid had been given, the only definite bony abnormality found by the author was the projecting mandible and some increase in the size of the sella turcica.

In the radiographs of a girl aged 12 years, sent to me by *K. Abbott*, the cranial sutures were wider than normal, the vascular channels were marked, the pineal was calcified. All the temporary teeth were present except for the first molars. The sella was normal. The elements of the neural arches were not fused, the notch on the anterior surface of the bodies was present, but there was no sign of epiphyses. The epiphyses of all the larger bones were stippled as if ossifying from multiple nuclei. Only three carpal bone nuclei were present. The femoral capital epiphysis on one side showed the changes of *Legg-Perthes's* disease. The femoral shaft cortex was thicker than normal. The patient showed considerable improvement on treatment with thyroid.

Hyperthyroidism. The author has recorded a flask-like expansion of the lower one-third of the femoral shaft associated with some degree of osteoporosis.

C. C. Bartels and *G. F. Haggart* described two patients, aged 9 and 17. Both had multiple fractures associated with decalcification of the skeleton. The vertebral bodies appeared to be compressed into a biconcave shape by expanded discs and compression fractures occurred. *G. F. Beilby* and *J. C. McClintock* described 2 cases showing advanced ossification. A child of 4 had the ossification of a normal child at 9 and within the following 2 months the ossification had advanced to that of a child of 12 years.

OTHER BONE DYSPLASIAS

Characteristic changes in the bones are seen in Acromegaly, Arachnodactyly, Acrocephalosyndactyly, Myositis Ossificans Progressiva. These are described and illustrated in the chapters dealing with the anatomical distribution of the disorders. An interesting disorder of ossification, in which the epiphyses of the terminal phalanges are abnormally dense, is shown in Fig. 52. One author recorded it as an example of avascular necrosis. It was seen in the unusual dystrophy recorded by the author[44] (see p. 30).

for bones showing ossification in membrane and others in cartilage show defects. Perhaps the most striking radiographic feature of the condition apart from the defective ossification of the clavicles is the appearance at all ages of delayed ossification. In the infant the sutures of the skull and the fontanelles are wide and large and there is a large number of wormian bones. Even in early adult life the fontanelles and sutures may not have closed. The dentition is delayed and defective and the palate defective. The elements of the neural arches of the vertebræ may fail to fuse until adult life. The neck of the femur may show defective ossification in its middle third. As a result of this delay in ossification, the skeleton is insufficiently mature to withstand normal functions. The head becomes brachycephalic, the frontal and parietal and occipital eminences are exaggerated and the vertex flattened, as in some cases of osteogenesis imperfecta, the skull may appear to be expanded and settled down over the shortened base. The palate may show a sulcus or undue narrowing. The cranial base is relatively narrowed particularly over the middle fossa so that the mastoids are more medially situated. The accessory nasal sinuses are small or absent and the facial bones show the more diminutive proportions of the foetal face to the cranium. The nasal bone may not be ossified. The mandibular angles appear to be flattened out. The vertebral bodies retain their early characters, later they may appear to be wedge-shaped—the greater diameter being anterior. The posterior aspects may appear to be compressed by somewhat expanded discs. The scapulæ may be small, the glenoid shallow and may exhibit a fissure across the inferior angle. The defects in the clavicles may show anything from complete absence to a small defect, suggesting fractures. The extent of the defect is usually different in the two sides. One writer has stated that "at least three of the cases observed by the writer have been reported by thoroughly trained and competent röentgenologists, as un united fractures of the clavicles." In one case recorded by *Poynton* the outer fragment of the clavicle, pressed upon elements of the brachial plexus causing severe neuralgic pains which disappeared with removal of the clavicle fragment. Subluxation or dislocation of the head of the radius (bilateral) occurs in some cases due to defective development of the capitellum and the lateral condyle of the humerus. Degenerative changes with loose bodies develop in adult life. The pelvis shows the delay in ossification of the pubic bones, the symphysis is wide, also the sacro-iliac joints. The femora show coxa vara of the congenital cervical type. The characteristic changes in the bones of the hand are described on p. 27. The cause of the condition is not known but in view of the delay in ossification it is interesting to note that the mother of one child developed myxœdema 2 years after giving birth to the child. Cranio-cleido-dysostosis is not associated with the same type of delayed epiphyseal ossification as we see in myxœdema. These features are seen in some cases of progeria (see p. 43).

The papers by *M. Cohn, Fitchett, Klemmer, Snoke and Cooper, Pillsbury, Schüller and Netterstheim* contain details of interesting cases.

The condition which the author has called Peripheral Dysostosis is associated with bone changes in the hands and feet which resemble the changes seen in severe degrees of cranio-cleido-dysostosis (see Figs. 19 and 20, p. 28).

HYPOTHYROIDISM (see Figs. 10, 37, 104 A and B)

An account of the radiographic evidence of hypothyroidism in infancy and the changes in the ossification due to thyroid administration is given on page 20 and Figs. 10 A, B and C. Further evidence is given on page 44 on cretinism.

The distinctive radiographic feature in hypothyroidism is delay in ossification. The epiphyses appear and fuse with the diaphyses at much later ages than normal.

The shafts of the long bones have a thicker compact cortex and are more slender

changes described by *Albers-Schönberg* or *Léri* but they more closely resemble melorheostose than *Albers-Schönberg's* disease.

Several examples of Osteopoikilie have been seen by the author which bore a superficial resemblance to melorheostosis. Dense ovoid islands, isolated or merged together in the epiphyses, were associated with dense longitudinal striæ in the diaphyses. The longitudinal striæ appeared to develop at the metaphysis and gradually peter out as they receded from it (see Fig 310 B). A good example is illustrated by *L. D Baker* and *H I Jones*

Angiomatosis. Evidence of this dysplasia may be seen in isolated bones, or in all the bones of one extremity The author has not seen general involvement of the skeleton but such cases may reasonably be expected to occur In one case seen the innominate bone and all the bones of that extremity showed a coarse cancellous pattern of less density than the opposite because of the absence of compact tissue The bones preserved their normal general shape The most common isolated lesion is seen in the vertebræ (see p 451). Affected bones have not the strength of the normal and fracture with moderate trauma. Angiomatosis of the soft tissues or an extremity may also affect the growth and character of the elements of the skeleton involved (see Fig 46)

In some cases the angiomatous nature of the tumour is indicated by the appearance of multiple phleboliths. As in the cases described by *Maffucci* and *Kast* there may be associated chondrodysplasia (see Fig 42 F).

In 1922 *Léri* described and illustrated a condition which he called Melorheostose because the radiographs show irregular deposits of dense bone running along the periphery resembling candle drippings. Usually the bones of one limb only are involved. Other names including Osteosclerosis Osteosis Eburnisans Monomelica, Osteopathia Hyperostotica have been given to the same condition The pathology of the condition is unknown. It bears some radiographic resemblance to osteoperiostitis, see Fig 443. The author has found the condition to be very slowly progressive (see Fig 83) As in the other dysplasias the lesions may be bilateral, unilateral or monostotic. The aberrant bone is dense and its borders relatively well defined The irregular bosses of dense bone lacking the control of growth by normal function, may interfere with joint movements. The adjacent musculature may also be adversely affected.

Reference is made elsewhere by the author [9] to the specimens of arthritic spines in the Strangeway s collection which show an appearance one might expect to be produced if the ligaments had undergone ossification after a preliminary swelling of the fibres by a sort of mucinous degeneration. They look as if some viscid stringy substance had run down over the surfaces of the vertebræ, adhered more to one place than another and had then been ossified. This description may fittingly be applied to bones in the condition called melorheostose.

A brief description of the earlier reported cases is as follows :—

Léri's radiographs show a large dense hyperostosis around the hip-joint and along the outer side of the femur and fibula.

Kahlstorf shows a similar appearance in the lower end of the femur over the patella and the antero-lateral surface of the tibia, in a man aged 53 years.

Milano shows a case, a boy of 11 years, with an ivory like thickening of the inner side of the femur and further radiographs taken a year after show a dense strip of bone in the proximal end of the tibia and a dense spot in the astragalus.

In *Sicard's* and *Ragueneau's* case the dense new bone was limited to one side of a lumbar vertebra and the corresponding sacro-iliac joint surface.

Belot and *Mouchet* illustrate a similar radiographic appearance in the upper thirds of the femora in two dwarfs of Lithuanian origin.

The radiographs of *Junghagen's* [3] case show bands of dense bone extending from the lateral border of the scapula, along the entire length of the humerus and ulna, and through the scaphoid, semi-lunar os magnum and pisiform, to the second finger and the metacarpal of the first finger There is also evidence of some arthritic changes. The patient complained of vague pains in the affected limb.

Valentin's radiograph of the bones of a girl, aged 17 years, shows dense transformation of the metacarpal and first phalanx of the index finger and some carpal bones. Bands of dense bone of stalactite form pass from the head of the humerus to the glenoid and the neck of the scapula. Other bands are shown in the inner side of the head of the femur which pass along the shaft. The patella, tibia and the bones of the feet also show a patchy distribution of this dense bone.

About 50 cases have been described. Fig 83 shows the typical radiographic appearances

Reference has been made in the chapter dealing with Albers-Schönberg's Disease to a case described by *Wakeley* [7] as a case of marble bones The radiographs, taken by *Graham Hodgson* show transformation of the ilii and the shafts of the femora into dense bone—a patchy distribution of the same tissue is seen in the tarsus and metatarsus.

Billick has illustrated a similar appearance in a tibia, the femora, a radius, an ulna and a scaphoid of a man, aged 50 years. Neither of these 2 cases show the typical

may be indicated around any of the long bones, but the bones of the lower extremity are most commonly affected.

Healing is indicated by an increase in the depth of the dense metaphyseal extremity of the diaphysis, the ossification of the light zone, the reappearance of the cancellous trabeculation of the shaft, and the gradual absorption of the calcified subperiosteal hæmatoma. Radiographs of the affected bones, taken 5 or more years after the disease has been cured, will show lines near and parallel with, the extremities of the diaphyses, and a central area within the epiphyses in which few or no cancellous trabeculæ can be seen. The outer limits of this relatively structureless centre indicate the size of the epiphysis at the time of the disease. All evidence of the calcified hæmatoma previously shown will have disappeared.

The distinctive radiographic features of this and other children's diseases are shown in Fig 80 p 93

Excellent radiographs illustrating the various appearances seen in scurvy are to be found in the articles by *Bromer* [1] *Fraenkel*, *Kato* [1] *McLean* and *McIntosh* *Pelkan*, and *Wimberger* Details of the histological and biochemical findings are recorded by *H A Harris*, *Smith* and *Maizels*

When the condition occurs in association with osteogenesis imperfecta the subperiosteal hæmatomata may ossify and the normal shaft be absorbed within a coarse cancellous involucrum (see pp. 550–1). These hæmatomata have been mistaken for sarcomata.

A pneumococcal osteomyelitis with ossification beneath the expanded periosteum may give a radiographic appearance of ossifying hæmatoma. The history and local inflammatory signs help to distinguish.

Scurvy and syphilitic lesions, often bilateral, are very alike—the former usually occurs at a later age period than the latter A syphilitic infant at the age of 1 month may show a decalcified zone at the lower ends of the femoral diaphyses, separation of the linear dense extremity with calcification in bilateral subperiosteal hæmorrhages. If put on anti-syphilitic medication within one month signs of resolution can be shown and within a few weeks there will be little but the remnants of the hæmatomata.

Subaponeurotic hæmorrhage may be seen in scurvy

The radiographic appearances of leukæmia may be mistaken for scurvy

J Caffey [1] has recorded multiple fractures in infants with chronic subdural hæmatoma in whom there was no evidence of scurvy clinically or radiographically and no evidence of definite trauma. The relation of these features does suggest some underlying pathology of the hæmato-osseous system. The effect of vitamin C should be tried.

RICKETS (see Figs. 75 A and B 80 A–C, 251 A and B 288 289)

Rickets. This is a vitamin D deficiency disease with disturbance of the calcium and phosphorus metabolism to which infants born in the latter part of the year in the *first half* year of life are most susceptible, though the more marked clinical manifestations may not be so obvious until towards the end of the first year It has been shown by *Maxwell*, and later *Snapper* that the newly born infants of women with osteomalacia may exhibit the characteristic radiographic signs of rickets, *i.e.*, fœtal rickets.

The first signs of the disease are (1) *Cranio tabes*—softening of the bones of the skull, particularly in the lateral aspects of the parieto-occipital suture this may be patchy in distribution and in the well-marked case the bone acquires a rubber-like consistency (*see also* p 19).

(2) *Bossing of the skull*—giving it a square appearance which in a modified form may persist after cure. It may not be present.

CHAPTER XXIV

GENERALISED DISEASES OF THE SKELETON

SCURVY (BARLOW'S DISEASE) (see Figs 80 D and 164 D)

This condition was first described by *Barlow* in 1883 Prior to his communications it had been known as acute rickets.

The disease is due to the deficiency in the food of the infant, of the antiscorbutic vitamin C, which is present in the juice of fresh fruit and vegetables.

The disease commonly occurs between the ages of 4 to 16 months, but hæmatomata enveloping the whole of one or more diaphyses have been seen in the third month of life which readily responded to vitamin C administration (see Fig 491) It is probable that fœtal scurvy occurs in some cases it develops in association with rickets. The condition is not so frequent as formerly: thus 17 cases of scurvy but 834 cases of rickets have been seen by the author at the Welfare Centres in Birmingham during 8 years

Radiographic Appearances. Radiographs should be taken as rapidly as possible on films, without the use of screens using a soft radiation The author uses films in double wrappers with an exposure of one-fifth second.

The changes in the bones are best seen at the costo-chondral junctions, the lower end of the femur the upper and lower ends of the tibia, the lower end of the radius and upper end of the humerus.

All the bones show osteoporosis. They present a ground-glass appearance the cancellous trabeculation often cannot be seen and the compact cortex is reduced to the appearance of a thin pencil line.

The diaphyseal extremities show a dense linear metaphyseal periphery the so-called trummerfeldzone. The apparent density of this zone is intensified because it is in contact and contrast with its non-ossified metaphyseal cartilage, and on the diaphyseal side a zone of decalcified bone, or as the histologists report, a zone showing excessive proliferation of connective tissue—*Lehndorff's* gerustmarkzone. This "gerustmarkzone" is unable to withstand the ordinary stresses and strains to which the part is subjected, consequently it can be crushed, and the trummerfeldzone," the dense extremity can be readily displaced from its normal position. Radiographs may show therefore that this plate of dense bone projects beyond the limits of the remainder of they diaphsis as a thin spur and with the epiphysis it may be displaced from position. Such an appearance is not infrequent at the upper or lower ends of the tibia or femur and may be seen at any extremity Complete separation may take place through this decalcified zone at the upper end of the humerus or femur and the diaphyseal extremity may tear through the periosteum leaving the growth cartilage intact (see p. 121 and Fig 281).

The anterior extremities of the ribs frequently show a marked bulbous expansion. The shafts of the long bones in some cases show new periosteal bone as a thin line running close against the line of the cortex.

The epiphyses also present a characteristic appearance. The periphery is outlined as with a pencil, but the interior is structureless This appearance persists long after the disease has been cured

A subperiosteal hæmorrhage cannot be detected radiographically until calcium has been deposited within it, *i.e.*, there is a latent negative radiographic period. After this has occurred, the calcium being deposited at first on the inner side of the displaced periosteum, the periphery of the hæmatoma can be shown as a spindle-shaped shadow enclosing that of the shaft. In some cases the radiographs show that the hæmorrhage has detached the periosteum to the limits of the diaphyses, as in Fig 164 in other cases it is detached over a limited area only of one extremity Such hæmorrhages

(1) The junctions of the fifth, sixth and seventh ribs; (2) the distal epiphyses of the femur and proximal epiphysis of the humerus (3) the epiphyses of the tibia and fibula (4) the distal epiphyses of the radius and ulna and the proximal end of the femur

For routine radiographic examination of suspected children, small films of the wrist suffice to establish the diagnosis and the progress of healing

Such examinations can be rapidly made without unduly disturbing the patient. The area to be penetrated is slender and the bone can be brought into close contact with an unscreened sensitive film. The X ray exposure can therefore be very short and the resultant radiograph will show the fine detail of the cancellous structure.

The earliest changes seen consist of (1) loss of definition of the metaphyseal extremity of the diaphyses (2) osteoporosis diminution or obliteration of the compact cortex and increased coarseness of the cancellous trabeculation (3) alteration in the shape of the diaphyseal extremity the slight convexity of the normal being flattened out, or in the active child, cupped (4) in the well-established lesion the extremities present an irregular ill-defined, cupped deformity (5) pseudo- or true fractures may be seen. In spite of the marked changes of the diaphysis the epiphysis often preserves its normal shape Healing is indicated by increase in the definition and density of the diaphyseal extremity This becomes consolidated and the cupped deformity filled in by relatively dense bone. Between the latter and the cancellous structure of the shaft, a zone of variable thickness, showing a finer reticulation, is often to be seen for a few weeks. Some cases of leukaemia show somewhat similar appearances.

The following were the appearances seen in the active phase of some typical cases of rickets during the latter months of the second year of life :—

Skull. No definite lesion—the sutures appeared to be wider than normal.

Spine A mild form of the dorso-lumbar kyphosis seen in achondroplasia (see Fig. 530), the vertebral bodies are of good form and the ossification appeared regular

Ribs Anterior extremities expanded.

Humerus Upper end expanded—metaphysis splayed and woolly—two woolly epiphyses. Lower end expanded but contour of all bones at elbow joint entire and regular

Radius and Ulna Expanded, splayed and woolly at lower ends. Regular outline to radial epiphysis

Bones of Hands Growing ends of metacarpals and phalanges woolly Two carpal bones—outlines of both regular

Femora. Metaphyseal surface of capital epiphysis woolly—regular articular surface. Lower ends of femora and both ends of tibia and fibula splayed and woolly—epiphyses regular Bowing of lower thirds of tibia and fibula with suggestion of fracture—the articular surfaces of tibia directed inwards and downwards Growing ends of meta tarsals cupped—phalanges relatively normal—distal epiphyses eroded and conical.

Snapper illustrates the typical radiographic signs of rickets (fœtal rickets) in newly born infants of women with osteomalacia. The signs gradually disappeared with the administration of AT 10 (dehydrotachysterol) while the blood serum calcium increased from ~ 8 mg -10·8 in 4 months when the phosphatase had reached 31 9 units per c.c.

Late rickets may be found in adolescents and young adults. In these the striking radiographic feature is the thick metaphysis, irregular cupped diaphyseal extremities associated with osteoporosis appearances resembling those seen in renal rickets but they respond to anti-rachitic measures.

These appearances are illustrated in Fig 80 p. 93, and contrasted with the appearance seen in the same situation in other bone disorders of childhood.

An excellent series of radiographs illustrating the appearance of the bones at the wrist and knee in rickets is to be found in *Wimberger s*[1] article.

(3) *Rosary* Expansion of the anterior extremities of the ribs at the costo-chondral junctions. Though the rosary may be recognised clinically before X ray changes can be detected, the latter rapidly follow and are usually to be detected before the enlargements of the limb joints can be detected clinically. It is known that histological evidence of rickets can be detected in the costo-chondral junctions a week or so before there is either clinical or radiographic evidence.

(4) *Joint Swellings* Radiographic evidence of disturbance of ossification at the articular growing extremities of tubular bones may be detected before clinical signs are present. *The radiographic evidence is most marked and first marked at the most actively growing metaphysis*, i.e., in order—lower end of femur upper end of humerus, lower end of ulna, lower end of radius, upper end of tibia. The last affected is soonest mended, i.e., following treatment the upper end of the tibia responds first, the lower end of the femur last.

(5) *Other Symptoms* *Pallor sweating, inactivity flabby musculature, distended abdomen* may be present. A child may appear to be well nourished yet have rickets. A less well nourished child may be free.

Treatment. The disease usually responds to cod liver oil and ultra violet treatment, whether this is from a lamp or the sun, but the most ready response and general improvement is seen when cod liver oil or its equivalent is administered to a patient living outdoors with plenty of sunshine. On this treatment radiographs show within 2–4 weeks signs of healing which is usually complete in 3–4 weeks. Radiographic evidence of healing usually precedes the disappearance of the more prominent clinical signs.

Rickets is the commonest disease in children to show bone changes, and, though the severe degrees of bone deformity are rarely allowed to develop, many early cases of the disorder can be discovered by routine radiographic examination of children at Welfare Clinics. 884 such cases have been so diagnosed by the author at the Carnegie Infant Welfare Centre in Birmingham during the years 1920–1934.

From a correlation of the histological and radiographic findings in a large number of cases of rickets, *Wimberger* decided "that the interval of time between the first histological rachitic change and the first radiographic change is certainly as long as several weeks, and that certain cases which never progress beyond the slightest grade of rachitic disorder can never be diagnosed in X ray photographs." The same statements can, of course, be made respecting mild affections of any bone disorder.

Nevertheless, routine radiographic examination of children with suspicious signs will establish the diagnosis long before the disease has produced changes which would result in any permanent deformity of the bones. Even in the cases which have been neglected until marked bony deformity has been produced, judicious treatment, while the condition is still active and before the deformities have consolidated, will result in obliteration of most of them (see Figs. 75, A, B).

Bones radiographed a few years after the disease has been cured are indistinguishable from the normal, and in this way they differ from the appearance of the healed bone lesions of scurvy. The pelvis only may retain the pressure deformities contracted during the active phase of rickets.

Infantile rickets may occur in association with Albers-Schönberg's disease and mask the latter (see p 550).

Radiographic Appearances. The most striking radiographic signs of rickets are seen at the points of endochondral ossification and they will first be manifested in those areas where growth is proceeding most rapidly.

From histological examination *Schmorl* considers that the changes develop in the different areas in the following order:—

and the epiphysis may be displaced by slight trauma or during ordinary functional activity Examples of slipped epiphysis of the head of the femur are described in a previous chapter (see p. 246.) Radiographic examinations at intervals may show a marked fluctuation in the amount of osteoid tissue as indicated by the depth of the metaphyses. Examples have been seen in which the metaphyses measured nearly ½ inch in depth at one time, and other radiographs after a month's interval showed a normal narrow metaphysis. The amount of osteoid tissue is probably dependent upon the severity of the causative factor

All the metaphyses may show similar changes, including those of the vertebral bodies. Instances of the development of *Schmorl's* disc nodes have been seen in association with these metaphyseal changes. The signs of Legg Perthes disease may appear as an additional feature (see Fig 253)

No changes have been seen in the skull in this type.

Type B Patients showing this type of bone change are suffering from a severe metabolic disturbance. They are usually dwarfs, with all the clinical signs and symptoms of a grave renal disorder

Radiographs show osteoporosis of the whole skeleton. The long bones exhibit shafts consisting of coarse cancellous tissue only often with multiple pseudo-fractures.

Fusion of the epiphyses and diaphyses is delayed. The metaphysis is considerably deepened owing to the large amount of osteoid tissue, and the opposing metaphyseal extremity of the diaphysis is very irregular in its ossification and outline (see Fig 77).

If the patient lives long enough for fusion of the epiphyses and diaphyses to occur a polyarthritis may develop which is manifested on the radiographs by blurring of the outline of the articular surfaces, the bones retaining the characteristic osteoporosis and coarsened cancellous trabeculation described. An example of such a case occurred in the author s series. All the arteries, even those of the fingers may show calcification in relatively young people.

The long bones of the lower extremity the pelvis and the spine exhibit pseudo-fractures and profound pressure deformities, which may be as severe as those seen in the worst degrees of osteomalacia.

The patient, the radiographs of whose hand is shown in Fig ~~ showed a triradiate pelvis of a very severe degree into which the lumbar vertebræ had sunk. The radiograph of his head is shown in Fig 433. The radiographic appearance of the skull is distinctive it may suggest the map-like skull in xanthomatosis described by *Schüller* and that of the case of osteomalacia described and illustrated by *Donald Hunter*

Another radiographic appearance was seen in the skulls of cases whose general condition was not so severe as the above. These cases showed multiple rounded opacities of varying sizes in the bones, an appearance rather like that seen in some cases of osteitis deformans.

The radiograph of a woman aged 26 years, diagnosed and treated as a case of cœliac disease since infancy showed bone changes which resemble those seen in cases of osteitis fibrosa cystica associated with hyperparathyroidism. The limb bones and pelvis showed marked general osteoporosis, bending and pseudo-fractures, and the skull showed round discrete islands of condensed bone, with a large area of rarefaction near the vertex and occiput.

In several cases which came to autopsy large parathyroid glands were found Except for the absence of cysts the radiographs were indistinguishable from hyper parathyroidism. In chronic renal disease with secondary hyperparathyroidism, the serum calcium is diminished and the inorganic phosphorus raised, the bones show the decalcification of Type B and in addition there may be calcium deposits in the extremities

Figs 251 and 252 show the appearance in the pelvis and hip joints. In the neglected cases bowing of the long bones, particularly of the lower extremities, is seen.

The lower third of the tibia and fibula may show a marked antero-lateral convexity Bowing of the femoral shafts or asymmetrical growth at the lower end frequently results in either bow leg or knock knee. Coxa vara deformity of the femur is also present.

When the bones have consolidated a dense layer of compact bone can be demonstrated along the concave aspect of the curvature, while the cancellous structure particularly at the extremities, is much coarser than normal.

The pelvis may be generally contracted or become triradiate in shape. The sacrum may be bent acutely forward about the level of the third body In the severe cases the vertebral column shows a general kyphosis and a definite basilar impression of the base of the skull. In the active phase the outline of the parietal bone is frequently woolly in appearance. The teeth in the dental sacs stand out with a density which is in marked contrast to the rarefied bones of the face and skull.

A Morton Gill has described 4 cases, in none of which was there any evidence of malnutrition, lack of sunlight or calcium, coeliac or renal disease, and in none of which did any of the known forms of therapy given over a period of several years, produce evidence of healing Healing occurs spontaneously when growth ceases. It is suggested that the fault may be a failure of utilisation at the site of growth. *Albright, Butler* and *Bloomberg* have published a description of a boy with rickets who resisted vitamin D until this was given in massive doses.

L. Gunther et al. report the case of a boy who suffered from rickets from infancy until 14 years of age in spite of treatment with vitamin D and supplementary calcium salts. The disorder was corrected by the daily administration of fish-liver oil high in vitamin D From tracer experiments with radioactive phosphorus they suggest that the primary defect in this condition is not failure of absorption of the bone salts but rather a failure of the calcifying mechanism.

In one case seen by the author radiographs of the infant during the first year showed rachitic-like changes in the diaphyseal extremities with very marked decalcification and compression of the vertebral bodies This persisted for several years and then the activity appeared to cease. A zone of osteoid tissue marked the phase in the shaft of the bones. Later rachitic-like changes recurred. The mother of the patient had severe nephritis which kept her in bed for several months during her pregnancy with this child but the child did not show signs of renal disease.

RICKETS ASSOCIATED WITH RENAL AND CŒLIAC DISORDERS

(see Figs 76 77 245 246 253 320 433)

In certain cases of renal or cœliac disease the bones show changes which resemble in some measure the rachitic changes of infancy These conditions result in defective growth and ossification, evidence of which is shown in the metaphyses of the growing bones. Renal rickets is associated with chronic interstitial nephritis, cystic disease of the kidneys or congenital hydronephrosis. The blood cholesterol is above normal, the calcium is low as compared with phosphorus, and the urea is high.

For the purposes of description the changes have been classed into types A and B

Type A The shafts of the long bones in this type show no osteoporosis or evidence of softening They may not show the contrast of compact and cancellous bone They have the straightness and form of the normal, but the metaphysis is deepened owing to the large amount of osteoid tissue between the extremity of the diaphysis and the epiphysis The extremity of the diaphysis is irregular and woolly in appearance This disorganisation of the growing zone reduces its capacity for bearing weight or strain,

invalidating consequently they are subjected to the stresses and strains of long-continued normal function—the need of food being the compelling factor

There are certain other causes for decalcification of the skeleton which are more acute and lead to early invalidism—in these conditions the bones are spared the super incumbent weights and the strain of function, and though perhaps even more decalcified than in osteomalacia, do not show the deformities and distortions of plasticity Fractures, particularly of the vertebral bodies are however fairly common. Marked osteoporosis of this nature is seen in association with such conditions as pituitary and suprarenal adenomata, biliary fistulæ and in that little-understood condition or conditions referred to loosely as senile osteoporosis In certain cases of generalised osteoporosis, associated with backache and perhaps collapse of one or more vertebral bodies, sternal puncture has indicated a diffuse myelomatosis though no typical radiographic lesions could be detected in the skeleton.

The radiographs of the bones in this condition show general osteoporosis and pressure deformities, the extent of which varies with the severity of the malady

The bones of the pelvis show all the deformities one would expect to get with softened bone. The sacrum is pushed down by the weight of the trunk acting through the lumbar vertebræ and the latter sink into the pelvis. The sacrum, being held by its sacro-iliac attachments, takes up a horizontal position, its superior border facing anteriorly and it is frequently bent forward acutely about the level of the third body as in neglected cases of rickets (see Fig 365 B) These features were well shown in the Broughton pelvis—a specimen in the Royal College of Surgeon s Museum. Photographs of the specimen were taken by the author (see Fig 368) The bodies of the ilia are depressed and flattened laterally by the weight of the viscera and bent forwards medially by the downward pressure on the sacrum. The femoral heads push in the lateral walls of the pelvic canal and the brim becomes triradiate, as in Fig 260. A number of pseudo-fractures may be shown extending through the entire length of the body of the ilium or through the pubic bone or ischium (see Fig 320).

The vertebral bodies are biconcave, being compressed by the expanded biconvex discs. The periphery of the bodies generally shows a greater density than the interior which shows little trabeculation.

The basilar impression in the base of the skull, due to the yielding of the base around the upper cervical vertebræ may be marked. The skull may show multiple small circumscribed areas of decalcification.

Donald Hunter has published an excellent radiograph showing this appearance and a later radiograph of the same patient showing a normal skull after anti malacic medication had been administered.

The radiograph of the skull in the case of renal rickets described by the author shows a similar but more extensive change in the bones of the skull (see Fig 433).

The long bones of the lower extremity are frequently bent. Any or all of the long bones may show pseudo-fractures or true fractures

Pseudo-fractures are seen not only on the convex aspect of the bent bones, as in osteitis deformans, but extending across the entire cross-section of any long bones which are not bent or markedly rarefied, as a linear zone of decalcified bone with parallel edges on either side, which are denser than the remainder of the bone (see Fig 48 C). In the pelvis such decalcified zones may be seen across the entire breadth of the ilium com mencing at the sacro-iliac joint surface, and displacement may occur between the opposing surfaces if they are subjected to strain. They also occur through the superior and inferior rami of the pubic bone (*see Fig* 320) In the shoulder area as a transverse zone through the neck of the humerus or the body of the scapula, commencing at the

of the fingers, while there is decalcification in the terminal phalanges and calcified arteries. Calcium deposits may be found in other sites, bursæ or kidneys.

In the case of a woman of 40 who developed acute hæmorrhagic nephritis in the latter months of pregnancy the infant was premature and died at birth. All the above signs were present. Pain in the joints and swelling of the finger ends had been noticed 1 year before. She died of uræmia a month later

In hyperparathyroidism before adolescence, the radiographic appearances are similar to Type B

Analyses of the published cases of renal rickets, with descriptions of the biochemical and radiographic findings in their own cases, are to be found in the papers by *Ashcroft Brockman, Fletcher Karshner* [2] *Parsons Swart* and *Teall*

Three theories have been put forward to account for these bone changes :—

(1) Chemical deficiency due to renal failure.

(2) Hyperparathyroidism, either primary or secondary to renal failure.

(3) *Pituitary diencephalic malfunction—this* producing the bone changes and the high calcium content of the blood from the latter in turn destroying the kidney

Idiopathic Steatorrhœa (Gee-Thaysen Disease) In this condition osteomalacia occurs in association with a changed small intestine pattern, dilatation of the colon fatty stools, tetany skin lesions and dwarfism. The serum calcium is generally low The plasma phosphorus may be low normal or raised. Spontaneous fractures may occur *General decalcification of the skeleton may be present.* The radiographic features of the bones as described by the author [41] (see Figs. 51, 103 and 321) are characteristic. The periphery of the bones is regular and entire They are composed of a somewhat coarser cancellous mesh which is rendered the more visible because of the absence of a compact cortex. Some bending of the bones of the pelvis and lower extremities occur in cases of long duration.

In one case seen by the author the cancellous structure of the terminal phalanges of the fingers was completely obliterated by the deposition of calcium within. The differential diagnosis of congenital pancreatic steatorrhœa and cœliac disease is given by *M H Harper*

Terrall has published an account of 2 cases of cœliac rickets The patients were sisters, aged 7 and 14 years. The radiograph of the first case shows pressure deformities of the pelvis and bilateral coxa vara, but those of the second case show profound disorganisation of the metaphyseal extremities of the diaphyses and bear a superficial resemblance to the appearance of chondro-osteo-dystrophy the chief difference being that the epiphyses, as in other cases of rickets, are relatively free from disorganisation

OSTEOMALACIA (see Figs. 48, 260 308)

The term osteomalacia is applied particularly to that adult condition in which, as a result of a deficiency of vitamin D the facility for the utilisation of calcium and phosphorus is impaired The bones develop an abnormal softness or plasticity and a tendency to bend as the result of long-continued strain rather than to break. The yielding of the bones places abnormal strains on the ligaments and muscles and the patient experiences aching pain particularly in the back and the thighs. The condition is sometimes called hunger osteomalacia. It shows a seasonal variation being found more commonly in the month of April In the majority of cases the serum calcium is low as in low-calcium rickets, with which it has many features in common. Like the latter it responds favourably to cod liver oil, irradiated ergosterol and ultra violet light. Though the bones are deficient in calcium and stability the condition is not primarily

humerus, and base of the coracoid process with an appearance of wide furrows across the scapula and ilia. These appeared to end in an apparent breach of continuity of the surface. An appearance simulating fracture of the pubis was present, and also bilateral coxa vara of the infantile type

In one case in the author's series the patient, a woman, aged 45 years, who had suffered with caries of the spine for 10 years, developed the characteristic appearance of osteomalacia following pregnancy

Similar deformities and pseudo-fractures are seen in renal rickets, but in this condition the other characteristic features will be present (see p 329)

Reference has been made in the chapter on the spine to a case of osteomalacia of the spine of a youth, aged 13 years. None of the other bones of the skeleton showed evidence of the malady

Preston Maxwell has published an interesting paper giving the details of an investigation of cases of osteomalacia in China.

The papers of *Löw-Beer*[1] *Looser*[1 and 2] and *Salinger*[1 and 2] contain radiographs illustrating the typical changes.

OSTEOPOROSIS AND PLASTICITY OF BONE

Features of Normal Bone. The histologist *Reichert*, promulgated the concept that bone, cartilage, tendon, fibrous, elastic, and adipose tissue, derived from the mesenchyme are all adaptations of or developments from the primitive connective tissue. Subsequently *Leriche* and *Policard* brought forward evidence in support of their suggestion that these mature tissues may be induced under certain influences to revert to their primitive state and then undergo ossification. They consider it is only in this way that cartilage or membrane is substituted or transformed into bone. The embryonic connective tissue consists of cells in a collagnous matrix composed of a fine fibrillar network infiltrated with a very viscid, gelatinous base. The impregnation of this matrix with phospho-calcific mineral matter permits of the setting of the matrix and the formation of bone. The part which the bone-cell takes in these activities has been a matter for considerable discussion. While by some it is thought, either by its secretion or by its degeneration, to be the origin of the pre-osseous substance, by others it is assumed that the latter results from physochemical changes in certain pre-existing connective-tissue elements while the cell exhibits little but osteolytic characters. The normal shape of the skeletal elements is laid down in the primitive mosaic and it has been shown experimentally that, even if these are separated and then cultivated, they develop their general characteristic features. Though the arrangement of the cancellous trabeculæ and the prominence of muscular attachments are modified by function, the general features of the perfect model are preserved by the balance of muscular tension and the strength hardness, rigidity and resilience of the bone. The features are changed if the balance is upset, when the relative stresses and strains are diminished or increased relative to the elasticity and strength of the bones. As a result the affected elements bend and certain characteristic deformities are produced unless steps are taken to neutralise the abnormal influence. Normal bone possesses a balance of strength, hardness elasticity and rigidity which is determined by the solidity and form of its structure, the condition of the fibrillar base, the comparative amount, cohesion, nature, and condition of its matrix, and the calco-phosphate mineral elements which it holds together

Prior to the deposition of mineral matter the pre-osseous tissue is plastic and can be compressed and deformed by stresses and strains—the lasting effect of which will be dependent upon the time for which they are continued, the changes wrought in neigh

thickest axillary border In the forarm through the shafts of the ulna and radius, often at the junction of the middle and lower thirds, but other sites are not infrequent. In the hand through a metacarpal or phalanx. In the femur through the neck or as a transverse zone across the base of the lesser trochanter In the leg through the upper or lower thirds of the tibia or fibula. These zones have been described by *Looser* as "umbauzonen." He regards them as end products of a rebuilding process. Such zones often show a symmetrical distribution and appear without any known trauma. There are, however arguments in favour of their being caused by trauma. They are found in most of the bone diseases in which softening or bending occurs on the convex aspect of the curvature at the point one would expect a bent article to fracture. They frequently do not extend the whole width of the bone, a feature which is seen when a semiplastic rod is bent. *Wilkinson* has recorded a case of osteomalacia, a woman of 40 years, who always had pain at a point, which subsequently showed on the radiograph as a pseudo-fracture.

It is conceivable that the fragile cancellous trabeculæ do fracture, but the periosteum and more fibrous elements of the bone remain intact. Localised absorption of fractured cancellous tissue results in the zone of decalcified bone. Though the borders of these recent lesions usually show no reactive sclerosis, in some cases they exhibit an increased density suggesting a pseudarthrosis. As the radiographs indicate, the zone is devoid of calcium, and is therefore relatively weak. Marked displacement, as in true fracture will occur at the site, unless it is relieved of pressure and strain: particularly at such sites as the upper end of the femur and the pubic bone.

The case published by *Milkman* a woman of 43 is most instructive. It shows these pseudo-fractures in the subtrochanteric area of both femora, the axillary border of the scapula, the ribs, the ulna, etc. No less than 48 in all. There was some degree of general osteoporosis. The condition was kept under radiographic inspection over 6 years and was found to be slowly progressive. It failed to respond to any medication and ended fatally Material from the zones was examined histologically but the only feature it indicated which called for comment was increased vascularity

Hunter described a case of osteomalacia which showed these transverse zones of decalcification as well as profound disturbance of the bone of the skull. His case responded to treatment with a diet of high calcium content together with 15 gm. of calcium lactate and two tablets of radiostol daily Radiographs showed that the pseudo-fractures were healed within 6 months.

Froehner recorded a case of osteomalacia with pseudo-fractures in a patient, a woman aged 45 years who had native sprue. She had marked intestinal disturbances and severe anæmia. She was treated with vigantol and campolon intramuscularly and calcium-Sandoz orally with a diet poor in fats Her condition improved, the bone pains ceased and within 8½ months callus was visible at the site of the fracture.

Generalised osteoporosis of the skeleton, most marked in the spine and pelvis, occurs in Basophil adenoma of the pituitary and in adenoma of the suprarenal. Multiple compression fractures may be found in the spine without any definite history of trauma.

An interesting case has been published by *Michaelis*

The patient, a youth of 18 years of age, complained of discomfort in his feet The following year he complained of diffuse pain, particularly on the right side of his feet ankles, knees, hips pelvis and sacrum The condition was diagnosed as hunger osteomalacia, but 5 years after this, the diagnosis was changed to multiple myeloma. No Bence-Jones protein could be detected in the urine The blood picture was normal except for an increase in the lymphocytes.

Radiographs of the skull showed circumscribed areas of rarefaction in the parietal bone The vertebral bodies showed a biconcave deformity with corresponding swelling of the discs. The bones of the forearm and hand showed a number of pseudo-fractures having dense borders. Similar changes were seen in the tibia, the shafts of the metatarsals, the neck of the

weakness of the spinal musculature, the curvature progressively increases in spite of fixation in the spinal jacket. The vertebral column with its processes and ribs undergoes very considerable moulding and the most extreme form of deformity may ultimately result.

The following is an example of this type of case :—

M. B., female aged 6 in 1927 was found to have a left dorsal scoliosis, the lower curve of which appeared to be corrected by suspension. She was put into a plaster case and in 1929 her report card stated that "it appears to be holding her well." On January 30th, 1929 the general alinement of the body was noted as good. On August 14th plaster was removed and a note stated that the deformity was not increasing Block leather support with double crutches were provided, and on October 6th, 1930 the report states : "Is standing better now" on November 9th, 1933 the report states deformity stationary Similar reports continue to record the clinical findings, but examination of the series of radiographs taken regularly since the condition was first recognised show a progressive development of the deformity and now the curvature is so extreme that the upper border of the 11th dorsal vertebra is on the same plane as the lower border of the 3rd.

The progressive development of this extreme form of curvature indicated that neither the plaster case nor the block leather supports were able to check the deformity Immobilisation in bed during the early stages, perhaps for two years, with exercises, may correct the balance and so prevent the progressive development of the curvature.

As indicated on pp 550–2 hæmatomata at the site of injury with or without definite evidence of fracture may be large and readily show a deposit of calcium and ossification. Massive lesions of this nature may be seen in infants and have been mistaken for sarcomata. Displacement of an epiphysis may occur as in Fig 210 A, giving the signs of a neurotrophic joint. Both the latter lesions may occur in infantile scurvy

PLASTICITY DUE TO GENERALISED CHANGES IN THE BONE

Those cases of osteogenesis imperfecta which survive birth and live to adolescence or adult life show in the early months and years a skeleton rather lacking in density but otherwise of normal shape and size. Depending on the gravity of the disorder we see the development of changes More pronounced than in the paralysis, we see a concentric atrophy of the shafts of long bones while the diaphysial extremities appear to be markedly expanded by their normal development. At this stage the skeleton exhibits a marked plasticity and develops deformities, the extent of which in any part are dependent upon the gravitational and muscular pulls. The head takes on a tam-o-shanter form with its vertex and sides tending to gravitate over the base—the latter tending to fold over the upper part of the spine. The vertebral bodies are compressed to half or one-third of their depth—though the discs preserve or even appear to exceed their vertical dimensions.

The vertebral epiphyses appear to be activated to earlier ossification, so that ossific nuclei may be readily demonstrated in them as early as the sixth year The ribs show a marked gravitational bending from their necks they become sharply directed downward. The bones of the upper extremity may almost or entirely escape in the lesser degrees of the dystrophy but in the severe forms the shafts of the long bones are slender and exhibit bending due to the superincumbent weight on the plastic bone during crawling But it is in the lower extremity that we see the major deformities of the plastic bone. The pelvis may be so plastic that it is compressed and distorted by the multifarious gravitational and muscular pulls until it assumes a wind-swept appearance The femora exhibit large extremities composed of wide-mesh cancellous tissue with but a thin periphery while the shafts gradually become slender rods of compact bone In their earlier stages of development such shafts are relatively brittle, but later

bouring tissues, and their shape and position at the time setting of the matrix takes place. With the deposition of crystalline salts of calcium, such as we see in calcification, no material contribution is made to the rigidity or strength of the bone. We see this in the skeleton in fœtal osteogenesis imperfecta where all the bones show a granular appearance and multiple foldings indicating a lack of cohesion of the mineral elements—a friability rather than a plasticity This feature is also seen in one stage of avascular necrosis of bone where the dead fragment collapses or even crumbles within its cartilaginous or membranous envelope. On the other hand, with the incorporation of colloidal calco-phosphate mineral matter the pre-osseous matrix appears to undergo a rapid setting which may be likened to that of re inforced cement and the bone acquires a rigidity resilience, and a relative fixation of form which is unaltered by normal function. Normally ossification commencing in an ossific nucleus, spreads uniformly and gradually from the regular centre to the periphery of the cartilaginous mass. It is not deformed by the normal stresses and strains of function of the growing child.

Effect of Irregular Ossification. If however the ossification in any site is irregular and multiple irregular ossific centres develop throughout the cartilaginous structure, this structure will not be capable of withstanding normal function, and, because with the irregular deposition of mineral matter it has lost its elasticity and taken on the characters of a plastic substance, it can be compressed and deformed. Examples of this can be seen in hypothyroidism. In the fœtus and young infant with this deficiency the ossification of the vertebral bodies is irregular and the keystone of the general spinal curvature, which is in the dorso-lumbar area, may collapse, resulting in stunted growth of the affected body and the development of a kyphos while in the older child the femoral capital epiphysis, which exhibits a similar defect in ossification, is splayed out over the upper end of the diaphysis so as to resemble the appearance of healed or healing Legg-Perthes disease or deformed into the beak shape which is most commonly seen in cretins (see Fig 203 B.) In the condition to which I gave the name chondro-osteodystrophy we also have multiple ossific nuclei; consequently in this disease primary and secondary centres of ossification will be deformed according to the pressures or muscular strain to which they are subjected during the irregular incomplete phase of ossification. In a later portion of the paper more attention will be paid to similar deformities of the skeleton due to localised plasticity induced by trauma or disease.

INFLUENCE OF PARALYSIS ON THE SKELETON

With the cessation of function occasioned by paralysis there occurs a gradual decalcification of the bones of the affected part eventually all the cancellous tissues within may be absorbed and the compact cortex considerably reduced in thickness; yet with the patient immobilised little change occurs in the outward form or position of the bones. Compared with the opposite normal limb a concentric atrophy of the shafts may later be seen which is emphasised by the more normal-sized extremities. The spine under those circumstances is not subjected to defective balance and the normal curvatures are more or less preserved. With the patient up and about with one paralysed lower extremity the bones of the latter appear to be affected by a gravitational pull The angle of the femoral neck with the shaft is straightened out and dislocation may occur The os calcis and other bones of the foot also show the effect of gravity Scoliosis of the spine may occur but the most marked cases of moulding associated with abnormal curvature have developed in children following one of the exanthemata of childhood. Soon after recovery from, say an attack of measles, a slight curvature of the spine is noticed. The radiographs at this time may show curvature unassociated with any secondary moulding With the alteration in balance, possibly associated with an undue

tive that little addition has been made to our knowledge by the more recent developments

Radiographic study of the skeleton in Paget's disease reveals that the condition may commence in one bone or in several widely separated bones. It may commence as a subperiosteal change which on the radiograph in the early stage is represented as a lanceolate cyst like absorption of an area of the cortex of a bone which is elsewhere normal—the line of demarcation between the Paget lesion and the normal bone being fairly sharply defined progress of the lesion is indicated by stripping up of the periosteum by a V-shaped thrust into the normal tissue (see Fig 478).

When the whole periphery of the bony segment has become involved the normal compact cortex within is gradually absorbed and the bone develops an increased plasticity which permits of bending under ordinary physiological strains. Gradually the whole bone is changed. The rate of progress may be so slow that it may be 10–15 years before the whole bone is involved. This is important from a medico-legal aspect when the patient alleges that the limb was normal until a recent injury The disease may remain localised to the one bone for years, or it may then spread across the joint and involve adjacent bone without producing any appreciable alteration in the articular surfaces. In one case one rib was involved and the disease involved its vertebra and then its fellow on the opposite side—the other bones remaining normal. In the same patient the disease may commence in another bone as a localised endosteal change—here the cancellous spaces appear to be filled up with a mineral deposit giving the bone greater and uniform density In the smaller bones and the flat bones all distinction between compact and cancellous tissue may be lost in the uniform density but in the larger tubular bones like the femur a thickened cortex may give the bone the appearance of marked hypertrophy Such changes may occur without attracting the serious attention of the patient, *i.e.*, serious enough to seek radiographic examination.

In the acute phase the bone is plastic and marked bending may be unassociated with any breach of the surface but complete fracture may occur during simple unguarded movements. At a later stage the long bones exhibit the reaction to strain which we see in a banana when its curvature is increased by pressure. The concave aspect is condensed while the convex aspect shows one or multiple fissures running towards the centre from the periphery *i.e.*, incomplete fractures.

The disease not only involves the normal bones, but ossified ligaments, massive repair bone at the site of old injury or old inflammatory foci, and ectopic bone in the soft tissues, develop the Paget characters of adjacent bone. In many cases biopsy has been performed to establish the diagnosis, but nothing has been added in all these years to the description of the histological appearance included by Paget. Far more can be learnt of the condition by careful periodical X-ray examinations of the skeleton.

There is a condition called by *Elmslie* "fibrosis of bone," or more recently by *Lichtenstein* and *Jaffe* "polyostotic fibrous dysplasia, in which the skeleton of the individual gradually develops, locally or throughout its whole structure, a remarkable plasticity permitting of great deformity (see Fig 472). The localised lesions as they occur in the skull or long bones exhibit radiographic appearances which may be mistaken for those of simple cysts—the lesions are represented by clearly defined expanded segments of bone which are devoid of cancellous trabeculæ but yet they are denser than the simple cysts. Such conditions have also been mistaken for those of hyperparathyroidism, and operative measures for the removal of parathyroid tumour have been undertaken in many cases. The distinguishing feature is that all other parts of the skeleton present the appearance of normal bone, even that adjacent to the so-called cysts shows normal cancellous and compact tissue—there is no general decalcification. In those cases which

bending, in spite of muscular atrophy and an increased proportion of compact relative to cancellous tissue indicates a degree of plasticity of the bones. So deformed may these plastic bones of the lower extremity become that the limbs are functionless, and their encumbrance has caused the surgeon to consider amputation advisable. In the less severe degrees of the dystrophy condensation of bone may occur at the apex of the curvature—Nature's attempt to limit it. In the active phase of infantile rickets the bone is lacking in mineral matter and all ossification is irregular so that a considerable degree of plasticity of the bone exists which permits of bending and compression deformity of all parts of the skeleton by stresses and strains which would not affect normal bone. With healing of the condition Nature attempts to correct the deformity or prevent its greater development by buttressing the concave aspects of the curvature with stout compact bone, as recorded by *John Hunter* The deformities which occur in infantile rickets are copied in the adult skeleton with the development of osteomalacia, but in this adult condition the deformities become more profound owing to the increased stresses and strains to which the adult skeleton is subjected.

In the rickets associated with renal fibrosis, two types of change are seen. In *Type A* the bones appear to preserve their strength except at the metaphyses—these may disintegrate under pressure and permit of serious displacement. In *Type B* there appears to be an added factor probably associated with hyperparathyroidism this leads to softening of all bones; they become so plastic that extreme degrees of gravitation deformities may develop, and though the metaphyseal areas exhibit an even greater destructive change than in Type A, these sites are not subjected to the displacements we see in Type A.

In hyperparathyroidism associated with a parathyroid tumour a profound decalcification of the skeleton ultimately occurs, leading to marked pressure deformities, but, except in young persons, as the condition of the patient before marked plasticity occurs has been reduced to almost complete invalidism following multiple fractures and general weakness, the gravitational deformities seen in osteomalacia are not usually present. The type of decalcification in the earlier phases is distinctive and its recognition of the utmost importance for early diagnosis before deformity or fracture occurs. Though in the latter stages it is associated with destruction of large areas of cancellous tissue and the production of multiple cyst like structures, which has earned for it the title "osteitis fibrosa cystica," in the earlier stages these cyst like areas may not be found—there may be but a stippled osteoporosis of the bones with perhaps small areas of ill-defined cancellous absorption.

PLASTICITY DUE TO CHANGES WHICH MAY BE LOCALISED TO ONE AREA OF THE SKELETON

The most notable of the conditions in which plasticity is exhibited originally in one bone, while all other parts of the skeleton may be normal, is Paget's disease Unfortunately the novice who has not mastered Paget's description of the disease which he called "osteitis deformans," is apt to interpret the radiographic appearances of hyperparathyroidism as Paget's disease This has resulted in very serious delay in diagnosis of a condition which, diagnosed early can be treated with success, but which, after the crippling effects of fractures and invalidism, yields a relatively poor result to treatment. Hyperparathyroidism is essentially a generalised condition from the first whereas Paget's disease begins as a localised condition. Paget's description of the condition should be reproduced in all text books, for though he was, perhaps fortunately without the aid of radiography and more recent laboratory investigations which appear to detract attention from the patient his clinical observations were so accurate and exhaus

hip joint, which was normal, will show abnormal moulding of the roof of the acetabulum and later some condensation of the subarticular bone. Within a few years atrophy of the superior articular cartilage will be apparent, followed by the progressive development of osteo-arthritis—a very serious surgical problem in so young a person.

PLASTICITY AND OSTEOCHONDRITIS

Most of the secondary and some of the primary ossific centres develop the changes which have been included under the general heading osteochondritis. In the initial stages of the condition, when associated with necrosis of well-formed ossicles, the young bone develops an increased density and friability. As a result the affected bone is crushed or fragmented, but its articular cartilage is apparently spared. Later the interstices between the fragments appear to be infiltrated with living tissue which brings about gradual absorption of all the mineral matter from the fragments. During the whole of this phase the affected bone is plastic and can be deformed by pressure from adjacent bones. But the necrotic fragment is not the only bone which is affected. Reactive inflammatory changes occur in the adjacent living bone. It is decalcified, apparently with deposition of calcium in the dead fragment, and it also becomes so plastic that it can be deformed by pressure. Later as the dead fragment is progressively decalcified and reconstituted, the adjacent bone recovers its calcium and normal characters but any deformity produced during the plastic stage is fixed (see Osteochondritis, p. 640). We see it more commonly following fracture of the femoral neck or carpal scaphoid. The most important feature is that these necrotic fragments excite inflammatory reactive changes in the adjacent vascular bone leading to its decalcification and abnormal plasticity until the necrotic fragment has been removed or entirely reconstituted (see p. 640–9).

HYPERPARATHYROIDISM (Osteitis Fibrosa Cystica)
(see Figs. 78, 79, 89, 184, 819 A and B, 474 A and B)

Hyperparathyroidism is a slowly progressive disease, the nature of which may not be recognised for several years. In 49 cases the average time from the onset of symptoms to the clinical recognition of their significance was 4·6 years, due largely to the failure to appreciate the nature of the osteoporosis which precedes the cyst-like changes. It slowly brings about a progressive decalcification of the skeleton, which may not be apparent on the first radiographs, and consequent changes in the proportions of the chemical constituents of the blood. The serum calcium (normal 9·5–10·5 mg. per 100 c.c.) is raised to 12–16 mg. per 100 c.c. The serum phosphorus (normal 3–3·5 or even as high as 5 mg. per 100 c.c.) is lowered to less than 3 mg. per 100 c.c. There is an increased excretion of both in the urine and fæces. The serum phosphates (normal Bodansky units 2·5 per 100 c.c.) is raised to 18–20 + units per 100 c.c. After the condition has been established for several years and the bones demineralised, the serum calcium may not show the higher figures noted in the early stage of the disease, and as these are concurrent with a lower phosphorus figure, the latter may return to be within the bounds of normal. The outlook is regarded as unfavourable if the serum phosphorus is raised because of renal insufficiency. It has been suggested that, if the calcium lost from the body could be made up adequately by the diet, decalcification of the skeleton would be prevented. Some of the excessive calcium in circulation may be deposited in the kidneys, lungs, heart, vessel walls, stomach, etc.

The condition begins with lassitude, hypotonia, constipation, pains in the bones of the limbs, in the pelvis or back. The number of sites and the frequency of the bouts

are more generalised the defective segments show whorls of chondrous tissue, with or without calcification *of their peripheries. The localised areas are expanded,* in the skull producing an appearance which may be mistaken for leontiasis ossea, and in the long bones permitting of bending, particularly when the lesions are developed in the lower extremity

Localised inflammatory lesions in, or in the *neighbourhood of bones, lead to* decalcification and plasticity which permits of marked deformity unless measures are adopted to prevent it. The development of coxa vara following inflammatory lesions in the femoral neck is an instance. Following trauma to the hip-joint, or as the result of inflammatory lesions in or around the hip-joint, the *walls of the acetabulum become* plastic for a time and if subjected to pressure during this phase will be pushed by the femoral head into the pelvis—thus is produced the lesion referred to as protrusio acetabuli Consolidation of the protruded bone is brought about by the deposition of much mineral matter and unless the inflammatory reaction persists or recurs the deformity is stabilised The deformity might be prevented by immobilising the patient during the active inflammatory phase.

As I showed in a previous paper plasticity of bone may develop after union of fragments which had been fixed by metallic plates or pins, and the fixing screws or other fittings be torn from the plastic bone. This reaction in the bone has been attributed to electrochemical changes between the bone and the metal. Though attempts have been made to check it by using metals considered free from this action, my radiographic experience suggests that removal of the metallic support as soon as the radiograph shows bony union between the fragments, followed by a short period of immobility would give the better results.

CONDITIONS ASSOCIATED WITH REDUCTION OF NORMAL BONE ELASTICITY

In Albers-Schönberg's disease, certain forms of Paget's disease, and secondary carcinomata of the skeleton, though the affected bones are abnormally dense from their increased mineral content, they appear to have lost the characters associated with normal fibrous bone and transverse fractures occur as the result of trauma insufficient to fracture normal bone. In tabes dorsalis, though the bones appear to be of normal radiographic appearance, they often exhibit an unusual fragility and comminuted fractures occur the lack of muscular protection is probably a feature in these cases.

LOCALISED PLASTICITY OF BONE DUE TO TRAUMA

When a bone is subjected to persistent abnormal strain, reactive inflammatory changes are incited, localised softening of the bone occurs, and pressure deforms the plastic bone. This phenomenon is seen more commonly perhaps in the spine than in any *other region. Continued pressure leads to condensation of the opposing* bony surfaces and ossification of the adjacent ligaments—Nature's method of checking the growth of the deformity Any lesion, whether it be developmental, traumatic, inflammatory or neoplastic in origin, which alters the normal alinement or balance of the skeleton, will cause abnormal strains to be placed on some structure sooner or later this will show the reactive changes detailed above With the young person no disability or reactive changes on the radiograph may be detected because of possible physiological compensations, but as the strains of adult life begin to mount, symptoms develop and serial radiographs show a progressive change. A good instance of this is the young patient who develops a pneumococcal arthritis of one hip-joint which goes on to bony ankylosis. After a year or so he has accustomed himself to the normal fixation and certain compensatory activities have developed, but in the late 20's or early 30's the opposite

treated by J *Raffan* who kindly permitted me to examine them, are instructive. F.S., aged 12, 3/11/36. The skull appears to be slightly thickened and lacking in all details of its structure—some small islands of dense bone are shown in rarefied areas No fine

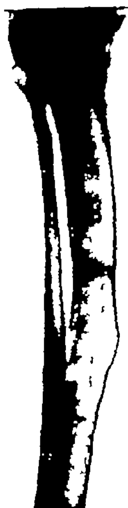


FIG. 474A. Hyperparathyroidism. Marked decalcification of bones, absorption of all compact tissue, and in the middle half of the tibial shaft all the cancellous tissue leaving a large cyst-like shell (November 3rd, 1936).



FIG. 474B. Hyperparathyroidism. Same leg as shown in Fig 474A but in January 1938, 13 months after removal of parathyroid tumour Note recalcification of bones and clear definition of the "cystic" area.

stippling Bilateral coxa vara and humerus varus were due to disorganisation of the metaphyses. Bones have no compact cortex. Marked bowing of the shafts of the femora and humeri which contained cyst like areas devoid of all structures was present (see Fig 474 A) Spontaneous fracture of one femur occurred. Changes in the bones of the hands and wrist similar to Fig 78.

increase gradually Renal calculi or colic may be the first cause for radiographic examination. *At this time the bone lesions may not be apparent or may be missed*

Localised tenderness may be noted over certain bones which, when superficial, may feel thicker Spontaneous fracture may occur The patient's condition slowly deteriorates and eventually becomes bedridden. Much interest has been aroused in this condition by the discovery that the bone lesions are often related to a tumour of the parathyroid gland and that improvement follows the removal of the tumour The parathyroid tumour may or may not be detected on clinical examination After its removal a normal calcium figure has been obtained within 3 months and within 6 months the skeleton (except for the cystic areas) will have regained some of its normal characters.

J H Crouch, et al., draws attention to the danger of acidosis following operation in hyperparathyroidism—it may occur with tetany They point out that it can be effectively treated by intravenous injections of sodium bicarbonate.

Radiographic Appearances. The radiographic appearances chiefly consist of generalised osteoporosis, absorption of the compact bone, and later cyst-like degeneration of the bone, with pressure deformities (see Figs. 810 and 474 A) The appearances of the bones of the hand, wrist and forearm are characteristic (see Figs. 78 and 79 and pp 91 and 92)

Skull. The bones of the skull in the well-established condition lose the sharp definition of their structure and show a stippled appearance, *i.e.* small pin-head opacities close together within a more transparent matrix. The outline of the outer table is less defined than normal. The appearance has been said to resemble that of osteitis deformans of the skull, but the features are distinctive.

The Vertebræ The vertebral bodies are softened and show a biconcave deformity The *internal cancellous structure may not be visible, but the periphery* of the superior and inferior surfaces is relatively dense. The discs are correspondingly swollen (as in Fig 411) The distorted pelvis shows a coarse cancellous trabeculation in which large cyst like areas may be shown. The femora may show coxa vara deformity bowing of *the shafts and protrusion of the head into the pelvic canal. The cancellous* internal structure of the shaft may be wholly or partly missing and this part may show a slight fusiform swelling, suggesting a cyst (see Fig 474 A). The cortex is thin and of a cancellous nature which may be indicated by irregularity of the external surface

The cancellous structure of the ends of the long bones may be represented by coarse strands in the long axis of the limb, between which the trabeculæ appear to have been absorbed. Similar changes may be seen in all the long bones, including those of the hands and feet. These features are well shown in Fig 78, a radiograph kindly sent *to me by Beath and Montgomery to whom I am much indebted.*

The costo-chondral junctions and fracture sites in the ribs may appear to be relatively dense.

Marked bending of the long bones of the extremities may occur The osteoporotic *condition of the bones is frequently associated with multiple calculi or diffuse calcification* within the urinary or biliary tract, salivary or pancreatic ducts: these may be the cause for the first radiographic examination They may continue to be the cause for symptoms even after the removal of the tumour

Attention may *be first focussed on the bone because of an abnormal* bending of the limb or the occurrence of a spontaneous fracture Radiographs of other bones may be invaluable in establishing the diagnosis The author obtains great help from radiographs of the hands for these are distinctive They also serve to watch progress following removal of the parathyroid *tumour—the decalcified terminal phalanges* soon show improvement

The details of the radiographs of the following case, which was discovered and

osteitis or inflammatory condition of the affected bones in fact, the title of his monograph is, "On a form of Chronic Inflammation of Bones (Osteitis Deformans)."

We now know that inflammatory conditions of bone can lead to deformation, though such conditions may present little resemblance, either clinically or radiographically to the entity described by Paget, and the evidence which we have before us does not lead us to regard the disease described by him as one of inflammation of bone such as we see as the result of bacterial invasion.

Cases presenting some of the clinical features we see in Paget's disease had previously been described even the term Osteitis Deformans had been coined by *Czerny* in 1873 but none of these earlier descriptions of patients gives us the characteristic picture of the disease which was so ably drawn by Paget to its intimate detail.

Even Paget stated, in his account, that he believed the disease to be so rare that "no one has seen a sufficient number of them to enable him to distinguish the disease, either clinically or anatomically from some which seem like it." He described but one case fully adding only a few notes of several others, but his description is so complete that, though many subsequent observers have had the opportunity of examining much larger series of cases with the aid of radiography and other ancillary departments of science of which he had not the advantage, we find little additional helpful information has been contributed.

I believe that the use of the names of our great clinicians in association with the diseases they have described is a good thing for it not only deservedly perpetuates their names and attracts students to read their publications, but it tends to prevent descriptions of one disease under many titles, and re-discoveries of features described by the original observers.

The following is a brief summary taken from Paget s description of his first case

The patient was a gentleman of good family whose parents and grandparents lived to old age with apparently sound health, and among whose relatives no disease was known to have prevailed. Till 1854 when he was 46 years old, the patient had no sign of disease either general or local. He was a tall, thin well-formed man, father of healthy children, very active in both mind and body At 46 from no assigned cause, he began to have aching pains of no great severity in his thighs and legs, chiefly after exercise. Two years later he consulted Paget who described him as a healthy-looking man, except for a swelling of the left tibia. The bone especially in its lower half was broad, and felt nodular and uneven, as if not only itself but its periosteum and the integuments over it were thickened. There was no tenderness on pressure Similar but less marked changes appeared to be present in the lower third of the femur The patient walked with full strength and power but somewhat stiffly No benefit was observed after potassium iodide and liquor potassæ which Paget prescribed. At a further examination 2 years later the patient still preserved his good general health and was enjoying an active country life but his tibia was now markedly thickened and bowed anteriorly his femur was thickened and arched forwards and outwards preventing contact with the opposite knee his pelvis widened on the left side and the right side of his skull was so thickened as to make his hats too tight

He had suffered little but annoyance from his clumsy left leg which failed to respond effectively to any treatment, though iodine in any form, appeared to do harm

In the next 17 years, Paget says, "I saw him rarely but the story of his disease of which I often heard may be briefly told, for its progress was nearly uniform and very slow

"The left femur and tibia became larger heavier and somewhat more curved. Very slowly those of the right limb followed the same course till they gained very nearly the same size and shape The limbs thus became nearly symmetrical in their deformity the curving of the left being only a little more outward than that of the right The knees became bent.

"The skull became gradually larger so that nearly every year his hats had to be enlarged. The inside measurement increased from 22½ inches in 1844 to 27¼ inches in 1876. In its enlargement, the head retained its natural shape and handsome features, and to the last looked intellectual, and his mind remained clear

"The normal curvatures of his spine became much exaggerated and its movements

A parathyroid tumour the size of a broad bean was removed.

In March, 1937 all signs of the active phase had gone. The long bones exhibited compact tissue but the cysts persisted now well defined the metaphyses were normal The skull has lost the stippled appearance. In January 1938 all the bones, including the skull, were now of normal appearance with the exception of the cystic areas, and these have diminished in size (see Fig 474 B). Except for the large cysts in a few of the bones, the skeleton, prior to the operation, presented all the features which I have found to be characteristic of Type B renal rickets, and it illustrates the parathyroid influence in such cases. At post-mortem on several cases of Type B renal rickets the parathyroids have shown general hypertrophy

Radiographs of bones which have previously shown the typical changes of hyper parathyroidism show an increase in density indicating a greater calcium content, a re-development of a compact cortex to the long bones, and an attempt at consolidation of the cysts after the causal parathyroid tumour has been removed. But, even when the bones have regained their normal appearance generally the cysts may persist and then resemble the lesions seen in localised polycystic dysplasia. Dense calcification occurs in some cysts and at fracture sites, suggesting that the bone is now taking calcium at the expense of the blood, and tetany may result.

Meyer Borstel [1] has published the details of a case with an interesting series of radiographs taken at intervals over a period of several years

The patient a girl aged 24 years began to have rheumatic pains in 1920 In 1921 she developed an exophthalmic goitre with amenorrhoea. The radiograph taken in 1921 shows a coarse cancellous trabeculation but no definite cyst. Another in 1923 shows the appearance of cysts, which by 1926 show considerable enlargement Her thyroid was removed and further radiographs in 1928 show healing and consolidation of the cysts A radiograph in 1927 shows a surface excavation of the tibia but a further radiograph of the same area in 1928 shows that this excavation is part of a subperiosteal cyst, the lateral walls of which are now ossified. The skull which was normal in 1922 showed irregular osteoporosis with dense islands in 1928

He considers the latter appearance to be an early sign of Paget's disease, and draws the conclusion that osteitis fibrosa cystica and osteitis deformans are manifestations of one and the same disease, an opinion which is also held by *Hirsch* [2] This conclusion is difficult to accept because the skull changes in these conditions are not identical; in fact, the appearance of the skull seen in some cases of renal rickets more closely resembles that of osteitis deformans than does the skull of hyperparathyroidism, and we know that these changes in the skull may disappear in the latter after the removal of a parathyroid tumour Paget's disease begins as a localised condition. Hyperpara thyroidism affects all bones.

It is conceivable that in this case of *Meyer Borstel's* the small tumour of the parathyroid was removed with the thyroid and that this was the cause of the subsequent healing of the bone lesions.

Many interesting examples of this condition have been described and illustrated, amongst which those by *Bradfield Compere Garland Gordon Taylor Hirsch, Hunter* and *Turnbull Dresser* and *Hampton, Lanford Knaggs* [3] *C I Royde C P Harris Platt* [1] *Short Wakeley,* [2] *Parkes Weber* [3] *Snapper* and *Telford* are to be recommended for study

PAGET'S DISEASE (OSTEITIS DEFORMANS) (see Figs. 65 152 153 A B and C, 190 216 287 297 318 391 435 475 A and B 436 476 A and B 477 A and B 478)

Sir James Paget described Osteitis Deformans in 1877

He used the term because he believed that the skeletal deformities were due to an

"The changes of structure produced in the earliest periods of the disease have not been observed, but it may certainly be believed that they are inflammatory for the softening is associated with enlargement and with excessive production of imperfectly developed structures with increased blood supply

With the exception of the statements to the effect that the disease is usually symmetrical that the limbs, however misshapen, remain strong and fit to support the trunk, that the disease is only observed in patients over 40 years of age and is inflammatory in nature all his observations are confirmed by all subsequent workers.

An interesting communication on 34 cases was made in 1934 by *Kay Simpson and Riddock*, who record the following biochemical findings.

"There is a diminished percentage of ash in the bone, which contains a much smaller percentage of calcium and magnesium than normal though, owing to the immense size of the bone the total calcium and magnesium content may be greater than normal. The serum calcium is not increased above normal, but may on the contrary be slightly below normal.

The plasma phosphorus is, almost without exception, definitely increased.

"In two advanced cases there was pronounced retention of calcium, magnesium, and phosphorus in the body with loss of sulphur In one milder case, there was a less-marked retention of calcium, magnesium, and phosphorus, with no loss of sulphur

The following tabulation sets forth an analysis of the principal features of the 154 cases recorded by the author [33]

PAGET'S DISEASE OF BONE

	Males: 82.		Females: 72.		Total 154		
Age Periods	20–30	31–40	41–50	51–60	61–70	71–80	81 +
	1	5	24	53	53	13	5
	Youngest 27		Oldest 87				
Distribution Site First Discovered	Pelvis.	Tibia.	Femur.	Head	Spine.	Humerus.	Os Calcis.
	58	37	22	13	13	8	8
Fractures	Tibia.	Femur.	Humerus.	Pelvis			
	7	8	5	3	Total 23.		
Malignant Changes	Pelvis.	Tibia	Femur.	Scapula.	Spine.		
	2	1	1	1	1	Total: 6.	

Distribution. The distribution of the disease between the sexes appears to be about equal. It occurs in all classes of society In some instances the disease appeared to possess a familial distribution. Thus, it was noted in parent and son or daughter brother and sisters, sisters. Numerous accounts have been published of the occurrence of the disease in animals, but so far I have been unable to satisfy myself that any authentic case has been published.

I have seen a condition of the bones of animals—horses, pigs, dogs, and recently a tiger in which there is a diminution of the thickness of the compact tissue and absorption of the cancellous tissues, associated with bending and sometimes bulging of the affected bones, but this condition does not bear any resemblance to that of Paget's disease.

Age Though I have been carefully watching for evidence of the commencement of this disease for many years, the youngest patient in whom I have been able to discover definite evidence of Paget's disease was 27 years of age Periodic radiographs during the past 7 years show the development of typical lesions. The author published the earlier series.[33]

reduced so that he diminished in height. His chest became flattened from side to side, his abdomen broadened and shortened His general appearance became simian, but his general health remained good

"In 1870 he had an effusion into the left knee and in 1872 his sight was practically destroyed by retinal hæmorrhage and his hearing became impaired

"In 1874 he complained of neuralgic pains and cramps

"In January 1876 the left forearm became increasingly painful and a tumour appeared, which grew rapidly and was thought to be cancerous by February but still his general health appetite and digestion appeared good.

"After this time however together with rapid increase of the growth upon the radius there was general failure of strength and emaciation and on March 24th, after two days of distress with pleural effusion on the right side he died 22 years after the commencement of symptoms."

Paget describes the striking attitude of the corpse due to the rigid deformities. At post mortem tumour nodules were discovered in the pleura spinal cord and embedded in the bones of the vault of the skull, but no sign of metastases elsewhere. The vessels were calcified. The report on the autopsy is a model of clarity and thoroughness.

In his general discussion of the disease, he says —

"In all the cases I have seen, the general appearance postures, and movements of the patients have been so alike that these alone might often suffice for diagnosis of the disease.

"The most characteristic are the loss of height, indicated by the low position of the hands when the arms are hanging down: the low stooping with very round shoulders and the head far forwards, and with the chin raised as if to clear the upper edge of the sternum the chest sunken towards the pelvis, the abdomen pendulous: the curved lower limbs held apart and usually with one advanced in front of the other and both with knees slightly bent, the ankle overhung by the legs and the toes turned out. The enlarged cranium, square-looking or bossed, may add distinctiveness to these characters, and they are completed in the slow and awkward gait of the patients and in the shallow costal breathing, compensated by wide movements of the diaphragm and abdominal wall, and in deep breathing by the uplifted shoulders.

"It begins in middle age or later is very slow in progress, may continue as a localised lesion for many years without influence on the general health, and may give no other trouble than those which are due to the changes of shape, size, and direction of the diseased bones. Even when the skull is hugely thickened, and all its bones exceedingly altered in structure the mind remains unaffected.

The disease affects most frequently the long bones of the lower extremities and *the skull, and is usually symmetrical. The bones enlarge and soften, and those bearing* weight yield and become unnaturally curved and misshapen. The spine, whether by yielding to the weight of the over-grown skull, or by change in its own structures, may sink and seem to shorten with greatly increased dorsal and lumbar curves the pelvis may become wide the necks of the femora may become nearly horizontal, but the limbs, however misshapen, remain strong and fit to support the trunk.

"In its earlier periods, and sometimes through all its course, the disease is attended with pains in the affected bones, pains widely various in severity and variously described as rheumatic, gouty or neuralgic, not especially nocturnal or periodical. It is not attended with fever No characteristic conditions of urine or fæces have been found in it. It is not associated with syphilis or any other known constitutional disease unless it be cancer

"In 5 out of the 5 well-marked cases that I have seen or read of cancer appeared late in life a remarkable proportion, possibly not more than might have occurred in accidental coincidences, yet suggesting careful inquiry

"It is only observed in patients over 40 years of age.

On April 20th, the cortex of the cyst like area was removed and the contents curetted out This was submitted for histological examination, and Professor Haswell Wilson recorded that "the sections show trabeculæ of rather degenerative-looking cancellous bone the interstices of which are filled with fibrous tissue The appearances suggest a very chronic inflammatory lesion. There is nothing to suggest tumour"

Radiographs of the area, on October 20th, 1936 showed that the cavity had been filled in, and the lesion appeared to have healed. The decalcified tissue in the lateral femoral condyle however had now become dense and the trabeculæ were obliterated by a deposition of calcium

Radiographs on March 15th, 1937 showed that the cortex of the whole area in the tibia was now considerably thickened (half an inch) and presented a transverse fissure running from the periphery to its cancellous border; deep to this, but extending the whole length of the thickened cortex, a band ¼ inch thick, of relative osteoporotic tissue was present and between this and the medullary cavity a further dense wall of similar thickness having coarse dense trabeculæ at its periphery The dense tissue in the lateral femoral condyle remained.

Radiographs on August 31st 1937 showed decalcification of the thickened cortex and a still further increase in length and depth of the decalcified band subjacent In the cortex and on a lower plane in the medulla two transverse fissures or pseudo-fractures were shown. The vertical trabeculæ throughout the head of the tibia now appeared to be separated and coarser than normal. The lateral femoral condyle showed a somewhat irregularly disposed area of increased density

Radiographs of the remainder of the skeleton at this date showed a general increase in the density of the fourth lumbar body the trabeculæ of which appear to be separated, coarser and denser

The skull showed an ill-defined area of osteoporosis in the frontal area and a densely calcified pineal gland. The patient felt perfectly well and no other abnormality was detected; he had no pain in his affected limb A further X-ray examination of the skeleton was made in January 1939 This showed no appreciable change in the radiographic appearance of the bones. He was still well and symptomless In 1943 (Fig 475 B) radiographs showed typical Paget's changes involving the upper half of the tibia. A sharp V-shaped line of demarcation showed the limits of the disorders. No further changes were seen in other parts of the skeleton. In 1946 patient ruptured the insertion of the tendo achilles Radiographs showed Paget's disease of os calcis

This case exhibits certain interesting features.

The disease began almost simultaneously in the lateral condyle of the femur and the antero-lateral area of the upper third of the tibia. In the case of the tibia, absorption of the inner compact and its adjacent cancellous tissue occurred, with the production of a lanceolate cyst like structure, and though this received radical surgical curettage, the disease continued to progress. In the lateral condyle of the femur the first sign was absorption of the finer cancellous tissue and its replacement by a few coarse, dense, vertical trabeculæ Later calcium was so abundantly deposited in the decalcified tissue that it gave considerable density to the area and obliterated all cancellous trabeculæ In spite of these well marked changes, the patient had no signs or symptoms of disease, and regarded the operative measures as being completely successful until 1946 when he ruptured his Tendo Achilles and radiographs showed fracture of the os calcis which had well developed signs of Paget's disease

One young man aged 20 years of age showed marked thickening of the cortex of the anterior surface of the middle third of the tibia which was of a coarse texture suggesting Paget bone but no opportunity of progressive follow up occurred.

I have seen a number of examples of bony dystrophy in young people, which, because they were associated with softening and subsequent bending of the bones, presented deformities bearing a superficial resemblance to those seen in advanced Paget's disease, and a radiographic appearance which has been, I think on insufficient data, likened to those of Paget's disease.

One distinctive feature should exclude them, namely these dystrophic conditions in young people are usually symmetrical and of equal duration, whereas, in Paget's

Case I Mr S F aged 27 years. Had worked as a toolmaker for 13 years. There was no evidence of any previous illness but he gave a history of an injury to the patella, in March, 1936

In April 1936 he first noticed a swelling over the tibial tubercle; this was not painful, though a little tender on direct pressure This was clinically regarded as evidence of a localised osteitis

A radiograph taken on April 21st, 1936, showed a lanceolate area of subcortical decalcifica-



FIG 475A. Paget's disease. Early lesion in man aged 28 years. Note lanceolate cyst like change on anterior aspect of tibia.

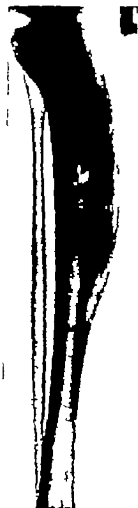


FIG. 475B. Paget disease of upper half of same tibia 7 years after 475A. See history of case on pages 604–5.

tion in the antero-lateral surface of the upper third of the tibia with obliteration of all cancellous detail within and a suggestion of slight bulging of the thinned cortical wall

There were also five or six dense coarse vertical trabeculæ equally spaced throughout the width of the lateral femoral condyle and a suggestion of decalcification in the intervening cancellous tissue The structure of the internal condyle remained normal yet the lateral radiograph suggested a general increase in the density of the femoral condyles. There was no swelling of the soft tissue and no change in the patella.



FIG. 476A. Spontaneous fracture in Paget's disease of femur



FIG. 476B. Same lesion as shown in Fig. 476A but 6 months later. Secondary malig metaplasia in lower fragment.

disease though the patient may ultimately show the imperfect symmetry of Paget's first case, the disease becomes manifest in one bone, and, though at the first complete radiographic examination of the skeleton further evidence of the disease may be obtained in other bones, these are usually isolated and the lesions are asymmetrical. For instance only one tibia or one femur or one side of the pelvis, may exhibit the characteristic features of the disease at the first examination or multiple irregularly distributed lesions are found, *perhaps the left tibia and the right femur or the right side of the* pelvis with one or more isolated vertebral bodies, with or without early changes in the skull. In this respect, the impression is given that the lesions are vascular possibly embolic in origin, so closely do they feature the distribution of carcinomatous metastases in bone

As will be seen from the table the disease is most frequent in the 50–70 age period, but may not be detected until the patient is 80 years of age. It must, however not be *inferred from this that the disease does not shorten the patient's life True a patient* may live for twenty or more years, as Paget's first patient did, but death often occurs after a much shorter interval from complications indeed, the disease may not be recognised until a serious lesion declares itself. Thus, one of Paget's patients developed signs of the disease and died four years after In some cases in the author's series no appreciable change occurred in the primary focus or foci in over 10 years.

Distribution of the Lesion. The table indicates that the disease is most commonly first revealed in the pelvis. This is entirely due to radiography for such patients present no typical signs or symptoms, and the lesion is revealed by chance during a radiographic examination of the spine, pelvis, or urinary tract, on account of indefinite aches and pains.

If the discovery of the typical appearance of Paget's disease in the pelvis or in a unit of the spine is made, a further examination of the skeleton may reveal yet other lesions.

The tibia is the bone which presents the earliest signs the clinician can recognise as suggestive, or even in some cases conclusive, of Paget's disease. Femoral lesions attract attention because of spontaneous fractures or dull, rheumatic-like pains and occasional sharp exacerbations. Headache is not the feature which is often associated with changes in the skull, but it may be associated with giddiness. More often it is the increase in size, causing tight fitting of the hat, which attracts attention. Though the skull may progressively increase to the thickness of 1 inch or more, the intelligence of the patient does not suffer In this way it differs from the condition known as Hyperostosis Frontalis Interna. The whole of the dura may be calcified.

The brilliance of Mercer's intellect was obvious, even after he had been affected by Paget's disease for twenty or more years.

Eventually the patient may suffer blindness because of retinal hæmorrhage, and deafness due to bone changes involving the middle ear is not uncommon. The accessory nasal sinuses are often much enlarged, and extensive dental sepsis is not uncommon.

Spinal lesions are usually discovered in the same manner as are those of the pelvis, and often at the same time.

The lesions in the os calcis were found on radiographic examination of subjects complaining of tender heel.

Lesions in other parts of the skeleton, notably the humerus, are discovered, following the radiography of spontaneous fractures.

COMPLICATIONS

Paget's disease may involve bone which had previously been deformed, atrophied, hypertrophied or affected by a disease process. The additional changes may be very confusing

Fractures. The most common complication of Paget's disease is fracture The

nearly 40 per cent of all osteogenic sarcomas occurred in association with Paget s disease

In 49 cases of malignant disease arising in Paget s disease 15 showed multiple foci



FIG. 477A. Radiograph (August 2nd, 1936) of leg of woman aged 63 years who had had Paget disease of tibia for 20 years. She sustained the fracture on getting out of bed July 31st, 1936. Not the area of destruction in the middle third through which the fracture has occurred. Endosteal malignant metaplasia.



FIG. 477B. Endosteal sarcomatous metaplasia in Paget s disease of tibia, September 17th, 1936. The tibia at the site of the fracture now shows complet disintegration.

Evidence of malignant disease has been noted within 2 years of the diagnosis of Paget s disease yet in other cases the disease has lasted as long as 35 years before this calamity occurred.

The malignant changes may develop in the subperiosteal or subdural tissue in the

affected bone has lost its normal elasticity and trauma, insufficient to injure the normal bone, causes the Paget bone to snap like a piece of chalk. As a rule, the fracture is *transverse as in chalk, but occasionally an oblique fracture is seen.* Such fractures usually readily unite, and if the bone fractures again it is unusual for the fracture to be in the same site owing to the efficiency of the repair which may be associated with an over-development of callus The fragments may fail to unite after months.

Serial radiographs of a fracture of Paget bone in the osteolithic stage may show in *the course of 2 or 3 weeks not only callus, indicating union, but the appearance of an* acute phase of the disease, such as is indicated in Fig 476, B, in the fractured extremity of one or other of the fragments (*i.e.*, the massive diseased bone may undergo reduction in its thickness and develop an area of osteoporosis, having a well-defined V-shaped boundary between it and the unchanged bone) Such an appearance may give rise to the *suspicion of malignant metaplasia at the site, a phenomenon which may* occur but *which is usually the determining factor of a spontaneous fracture and not a* subsequent event (see Figs. 476 A and B and 477 A and B)

Pseudo-fractures. Apart from these obvious fractures radiographs of affected bones frequently show transverse zones of decalcification running from the periphery of the convex border towards the medulla. These *may appear as slight indentations* or as fissures, running half way across the shaft. Such fissures often show borders which appear to be of slightly greater density than the adjacent bone.

Twenty or more such fissures may be shown through the convex cortex of the anterior surface of a bowed tibia. Such fissures resemble those which are produced in a semi-plastic structure like a banana when its curvature is increased by bending—the concave aspect is condensed, and the convex is fissured.

I have described these as pseudo-fractures, for they are not often associated with a true complete fracture perhaps a better name is incomplete fractures.

The early case which I have described presented such fissures, though but a small percentage of the section of the tibia was involved in the pathological process. Undoubtedly they are evidence of stress, and develop at the maximum point of tension. The trabeculæ of the cortex are, for the most part, running parallel with the axis of the shaft, and if the stress at both ends of the bone is great enough a crack will occur at right angles to the axis. In this condition of Paget's disease the bone has lost much of its elasticity and the stress apparently leads to breach of continuity of trabeculæ and to absorption of calcium along the line, which, if the stress be great enough, a fracture would occur and the calcium is utilised in strengthening the concave aspect of the shaft; for as we see in such conditions as rickets, new bone is mostly laid down on the concave aspect of bones which have been bent. It is probably on account of this latter process that it is rare to see any sign of these pseudo-fractures within the bounds of the concave cortex.

Though we may see a suggestion of calcium deposited on the borders of these transverse lesions, we do not see bridging of the peripheral extremity with new bone such as we always see in the true transverse fracture whether the latter is or is not accompanied by displacement of the fragments.

Malignant Changes. It will be remembered that Paget's first patient with this disease died as the result of malignant metaplasia. In fact, no less than 5 of the 8 original cases which he saw died from this cause. And though I have been able to see but 0 of my group with malignant disease, I do not think this will represent the total number when I have completed the investigation (see Figs. 477 A and B).

In this respect the analysis by Coley and *Sharp* of the cases referred to the American Registry of Bone Sarcoma, is pertinent. They found that in the age period 55-70

On examination a marked swelling was obvious over the upper thigh extending almost completely round the limb The swelling exhibited fluctuation suggesting a large fluid collection. A firm mass could be felt extending into the lower part of the right iliac fossa, which aroused the suspicion of malignant growth.

X-ray examination June 8th (Fig 287), showed the typical changes of Paget s disease in the whole of the right side of the pelvis—an irregular acetabulum a widened joint space and a sharply defined erosion of the head of the femur which I reported as indicating a Charcot's joint

June 15th, 1936 the swelling was explored by Mr T S Donovan, who reported " a large hæmatoma filled with serous fluid and large masses of soft, pliable clot."

The Wassermann reaction was strongly positive Serial radiographs since this time have shown a progressive development of a neurotrophic hip joint with the formation of a large extra acetabulum all the new bone exhibiting the features of Paget's bone

The typical changes of Paget s disease have been seen to occur in bones showing healed tuberculous lesions.

When the bones entering into the formation of joints are involved by Paget s disease the joint surfaces may remain intact for many years, and none of the radiographic signs of arthritis may develop, but when the disease develops in joints showing the changes of infective or osteo-arthritis, the abnormal bony structure, *i.e.*, osteophytes, ligamentous ossification, etc., develop Paget changes. Similarly when ossification occurs in such structures as the laryngeal cartilages, these also exhibit Paget characters.

Ætiology *Paget* believed the disease to be a chronic inflammatory lesion of the bones.

Knaggs assigns the cause to the absorption of toxins. A number of workers have regarded it as evidence of endocrine disturbance, the thyroid and parathyroid receiving the bulk of the suspicion. Others have suggested that the disease was due to syphilis, or perverted metabolism. It is not unusual to find several members of a family exhibiting signs of Paget's disease.

Moehlig suggests that there is a high incidence of familial diabetes, familial tallness, and familial obesity in patients suffering from Paget s disease.

In a number of cases, attempts have been made to attribute its development to a previous trauma. In the majority of cases it can be established from the radiographic appearances that the disease existed before the injury was sustained. In such cases, as is detailed in one of my early cases, trauma cannot be so readily dismissed as a causal factor

A number of radiographs have been published showing the characteristic features of Paget s disease, and the authors have attributed the lesion to chronic fluoride poisoning The fact that the lesions are often isolated or scattered would appear to rule out chemical or bacterial poisoning or endocrine disturbance. My opinion is that the exciting factor produces localised vascular disturbances concomitant with adverse influence on the bone structure The coarse bone structure bears some resemblance to that which is substituted for avascular bone.

Flemming Møller demonstrated that a large percentage of workers subjected to the inhalation of fluoride over long periods developed a uniform sclerosis of the bones and an ossification of the tendinous insertions. The appearances which he, and later *Roholm* demonstrated are on casual examination not unlike those seen in that type of Paget s disease which I have classified as the osteolithic type, but it is to be distinguished by the fact that the changes due to fluoride present a somewhat granular appearance and gradually develop with symmetrical distribution in all the bones, whereas in Paget's, as we have seen, the lesion may remain for years in one bone only

Somewhat similar changes in the bones to those described by *Flemming Møller* I have

scalp or as endosteal tumours. Multiple such deposits may be detected at the first examination. As with Paget's first case, we may see multiple subdural and subpleural metastases, but yet no sign of such lesions in the viscera. Whereas, in ordinary sarcoma visceral metastases, particularly pulmonary are the usual sequence.

In this respect, the recent paper by *Davie* and *Cooke* is of interest. They point out that "it is to be noted that while the large, frankly sarcomatous tumour masses in these cases partake of the nature of periosteal growths, and are attached to rather than growing in, the bones; the smaller benign looking tumours are embedded in the bony corticalis and resemble those seen in generalised osteitis fibrosa with hyperparathyroidism. In both cases the development of multiple foci of primary sarcomatous change appears to be undoubted.

"In each case the appearance of one tumour mass in association with bone is followed within a comparatively short time by the appearance of tumours in other bones, and in neither case did the post mortem examination show any intrapulmonary or other visceral metastases which might suggest that the numerous body tumours found at autopsy were the result of blood borne dissemination. In each case there was some abnormal feature of the thyroid and parathyroid

That malignant changes do arise from the endosteal as well as the periosteal tissues, will be seen from the radiographs which I[22] previously published of Mrs. E. S., who gave the following history :—

Mrs. E. S., aged 65 years came to hospital complaining of pain in her leg She stated that for 20 years her leg had showed signs of bowing and for the past 4 months she had experienced pain in it on walking Two days ago (July 31st 1936) when she got out of bed, the pain in her leg was more intense and after a short interval she fell on to the bed and injured the leg

Radiograph (Fig 477 A) (August 2nd, 1936) shows an area, roughly ovoid in shape situated at the junction of the middle and upper thirds of the tibia, throughout which all the bony trabeculæ had been absorbed A fracture of the cortex bounding this area is shown with no displacement The remainder of the tibial shaft show the typical appearances of Paget's disease.

A further radiograph (Fig 477 B) taken on September 17th 1936, shows complete disintegration of the middle third of the tibia and large quantities of amorphous calcium scattered throughout the soft tissue surrounding the bone.

The leg was amputated above the knee (September 21st, 1936) and the patient was discharged apparently fit (October 5th, 1936) but she developed lung symptoms within a few days, and died 10 days later

A similar lesion developed in the body of the scapula of a woman patient with Paget's disease. Deep-radiation therapy was given without any beneficial effect on the patient or lesion

Associated Lesions. It has been shown by a number of workers that Paget's disease is not usually associated with syphilis. When it is unusual clinical and radiographic features may become manifest, which tend to obscure the diagnosis

In the following case the patient Mr H. I., aged 54 complained of a swelling in the region of the left Tendo Achilles.

A radiograph (February 20th 1932 Fig 190) showed four well-defined irregularly shaped ossicles in the swollen area, and evidence of Paget's disease of the os calcis.

March 7th, 1932, the ossicles were excised from the body of the tendon by Mr F Wilson Stuart, and submitted for histological examination.

The histological report (G Haswell Wilson) was, "This consists of cancellous bone with very dense coarse trabeculæ Most of the space contains fat but in some there is calcareous *débris* in relation to which the bone has apparently developed. There is nothing to suggest why bone formation has occurred."

On June 8th 1936, he came to hospital complaining of a lump at the upper part of the right thigh which appeared to come suddenly three weeks before The swelling had been gradually increasing

seen as the result of carcinomatous invasion of the skeleton from a primary carcinoma of the stomach and œsophagus

Histology Little advance has been made since Mr *Butlin* reported to Paget on the histological appearance of the bone submitted to him, as follows —

"The whole microscopical architecture of the bone has been altered the structure appears to have been almost entirely removed and laid down afresh on a different plan and in a larger mould."

This excellent description not only characterises the histological, but also the macroscopical structure as seen on section of the bone and by radiography

Radiographic Appearances. The first radiographic evidence of Paget's disease in any part of the skeleton is an alteration in its density

The disease appears to commence either as an endosteal or a subperiosteal affection and the radiographic characters depend upon the age, chronicity and type of the lesion.

In the long bones, lesions present the appearance of acute halisteresis or of one of the following three mature types —

(1) Osteolithic.
(2) Osteoporotic or fibrous.
(3) Lithocystic.

These are illustrated in Fig 478

Certain outstanding characters are displayed in the skull, pelvis, spine, and long bones, and these are described under their respective headings. The transition from the acute halisteresis to the mature lesion is not usually seen because the disease, for many years, may be symptomless. The patient is generally found to have one or other of the mature type of lesion at the first examination. The typical appearances in the skull are shown in Figs. 485 and 486 and in the pelvis in Fig 818

The Femur A similar classification of the changes in the femora can be made to those described in the pelvis, but there are certain modifications owing to the shape of the bone. All forms lead to bending of the bones, owing to the superincumbent weight, consequently coxa vara deformity of the neck with outward and forward bowing of the shaft is usual.

The disease process may begin at either or both ends. I have never seen it commence in the middle third, though this is eventually included

When the disease affects the long bones, and this is particularly noticeable in the tibia, the affected segment is sharply cut off from the normal. As previously indicated, my impression is that the disease may spread *viâ* the periosteum and/or the endosteum. If *viâ* the latter the changes appear to be slower and the margins diffuse, so that the borders cannot be defined (see Fig 478), but if *viâ* the periosteum the impression is given of progressive but gradual elevation of the latter from the surface of the bone by a massive growth of subperiosteal osteoid tissue. The line of demarcation between the normal and the abnormal is usually V-shaped and sharply defined The affected segment is increased in width due to the new tissue, which is structureless in its early stages. The boundary of its medullary cavity appears to be more sharply defined than normally but the cavity is diminished in section. Some suggestion of the old cortex may be present, but ultimately the striæ defining this are absorbed and all trace of the former outline is obliterated. The rate of progress of this stripping appears to vary in different cases, but in one case I was able to measure fairly accurately; it appeared to be not quite ½ inch a year In some cases the disease appears in a more acute form (represented diagrammatically in Fig 478, No. 2) then the whole bone may be involved simultaneously

In this the periosteum appears to be elevated over a part or throughout the whole

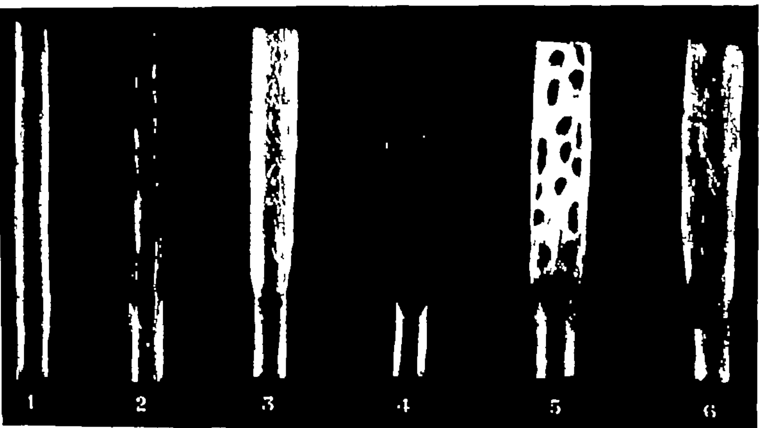


FIG. 478. Diagram of changes in the long bones in Paget's disease showing the sharp V-shaped line of demarcation between the diseased and the normal bone (1) normal bone (2) acute halisteresi ; (3) osteolithic type ; (4) osteoporotic type ; (5) lithocystic type ; (6) lateral radiograph of 2.

Treatment. In no case have I seen any alteration in the ordinary course of the disease affected by treatment, though some observers have regarded the alteration in calcium content, as the result of the exhibition of medicaments

Kay Simpson, and *Riddoch* in 1934 report that the administration of five grains of suprarenal extract three times a day relieved pain and give *Robert Milne* the credit for suggesting this empirical therapy They further state that the effect of cortical extract is being tried out.

Relief from the gnawing pain has been attributed to X radiation therapy and lineal osteotomy

Amputation has been performed, but as illustrated in the details of Case 1 and as with malignant disease until we can remove the inherent susceptibility of the rest of the body to the disease, it is unlikely to be a cure.

The author suggests that splinting or support of the affected tibia appears to be a reasonable treatment in that such a bone is liable to fracture and reduction of strain on the plastic bone cannot fail to relieve some of the symptoms

Sarcomatous changes have been recorded by a number of observers, notably *Genner* and *Boas*, *Wiering Carlo* and *Woolf*

Further illustrations are given by the author [33] *Schmorl* and *Junghanns Hallerman* and *de Gaetano*.

length of the shaft in a relatively short space of time and radiographs show a shaft with an attenuated old cortex markedly decalcified and surrounded uniformly by a *second osteoid like cortex of about a ¼ inch in thickness.*

At this stage of the disease the bone is very fragile and fractures may occur with ordinary movements of the limb. In the course of 6 to 12 months, this phase appears to pass owing to ossification of the new cortex, which appears to commence in the tissue adjacent to the periosteum and gradually involves the whole of the osteoid, so that the *bone now appears to be thicker and denser.* The new cortex may take on a uniform density similar to that described in the pelvis as the osteolithic type (see Fig 478, No 3), with little encroachment upon the medulla, or may exhibit the coarse fibrous texture of the osteoporotic type (Fig 478, No. 4) or the density of the lithocystic type (*Fig 478, No. 5), which obliterates all detail of the cancellous structure except for* multiple lanceolate rounded or ovoid areas often called cysts, containing little calcium, through which a few coarse trabeculæ may be recognised

Fractures of the femur are not uncommon. The most frequent site is just below the lesser trochanter and after this, the femoral neck and middle third of the shaft. Healing readily occurs.

Tibia. No bone presents the characteristic features of the disease more clearly than the tibia, and it is more frequently involved than any other long bone. It is this bone which exhibits the periosteal progression of the disease in an almost diagrammatic clearness. *No other bone so frequently shows the so-called pseudo-fracture of its* affected convex cortex. The tibia may become very massive, reaching more than double its antero-posterior thickness and exhibiting a marked forward bowing (see Fig 475).

The three types of changes previously described are met with in this bone as in the femur and pelvis.

Bones of the Foot and Hand. Of the small bones the one most frequently exhibiting evidence of the disease is the os calcis. In this bone the trabecular pattern is of a coarser and denser type and the bone is generally expanded throughout. Isolated sesamoids, metacarpals, metatarsals, or phalanges may show general decalcification or expansion *and thickening of the cortex in association with diminution of the medullary* cavity (see Figs. 65 and 159).

The Bones of the Upper Extremity and Thorax. The most frequent of the bones of the upper extremity to exhibit evidence of the disease is the humerus. This may show any of the four appearances illustrated in Fig 478 Spontaneous fracture through the middle third is not uncommon. Dislocation of the radius may result from expansion and growth of the bone compared with the ulna. Isolated ribs, or the whole of the ribs, the sternum, and clavicle may also present similar radiographic appearances, but it is uncommon to see these affected until a fairly widespread distribution of the disease has occurred.

Calcification of Vessels. A common finding on the radiographs of the extremities is the presence of calcified vessel walls.

Differential Diagnosis. Throughout the discussion, mention has been made of the similarity in the radiographic appearances of Paget's disease and secondary carcinomatous invasion of the bone chronic fluorosis, Albers-Schönberg's disease, osteomyelosclerosis, renal rickets—Type II, and Hyperostosis Frontalis Interna.

Chronic osteomyelitis, syphilitic osteitis, and endothelial myeloma are not infrequently mistaken for Paget's disease. The clinical and radiographic features of these conditions have been previously described.

A number of cases of Paget's disease have been treated as syphilitic periostitis. The radiographic features of the two conditions are usually distinctive

examinations be made particularly in those cases in which the symptoms persist certainly immediately before any active "remedial" measures are employed a further careful radiological review of the case should be made

The *reasons for this latent negative radiographic period* are :—

(1) Lesions must develop to a size which will permit of their recognition in the normal structures No lesion can produce radiographic evidence until it has attained a size distinguishable by the naked eye The size at which a lesion will be recognised is also dependent upon its position and whether or not it is associated with other lesions of a similar nature Many miliary lesions in the lungs, whatever their nature will be recognisable as such when they have acquired macroscopic size, but a few isolated lesions much larger in size may escape detection because of the variable pattern of the shadows of the normal lungs These macroscopic lesions become recognisable by size only when they are of different density to the normal tissues in which they are developing *i.e* either more or less transparent than the latter Very considerable destruction can occur within a bone and yet no indication of it may be detected in the radiographic appearances

(2) Lesions must produce a difference in density within the normal structures because a radiograph is but a register of the relative densities of all the structures traversed by the rays. Many lesions are of the same density as the normal tissues in which they are developing and so may attain great size and yet not register any evidence of their presence on the radiograph. The destructive process may be so diffuse at its borders that contrast density is not produced—tuberculous and secondary carcinomatous deposits in bone may thus escape attention until the periphery of the bone is broken. The greater the contrast density produced by the lesion, the more ready its detection and the less contrast density given by the lesion, the longer will it escape radiological detection Although of the same relative density lesions may become visible by producing deformity of the visible contour of the structure in which they are growing or of adjacent organs the radiologist is dependent upon such evidence for the detection of lesions such as gastric ulcer or carcinoma, brain tumour and the like.

The Duration of the Latent Negative Radiographic Period. The *time* required for the production of radiographic evidence of so-called *miliary lesions in the lungs* is dependent upon the nature of the exciting cause and the rapidity and extent of reaction of the tissues to this cause. The inhalation of nitrous fumes may produce radiographic appearances in a few hours, but the miliary lesions due to tubercle bacilli may not be recognisable for several weeks after the clinical evidence has suggested their presence. This may be of very great importance in the diagnosis of a lesion in bone.

The signs and symptoms of *pregnancy* are recognisable long before the radiograph will show evidence of it. It is rare to see radiographic evidence of the *fœtus* under nine weeks, and from then diagnosis depends upon the relative densities of the fœtal bones if these are not normally ossified as in osteogenesis *imperfecta*, the radiograph at full term may not reveal the *fœtus* as such The signs and symptoms of acute osteomyelitis are recognisable ten to fourteen days before the radiograph shows any departure from the normal to wait for radiological evidence before treatment would be to jeopardise the limb or life of the patient.

Following *injuries to bones and joints* particularly those injuries which materially impair the vascularity the radiographs may not show departure from the normal for weeks or months, although the clinical signs and symptoms have been continuous and might have warned the surgeon of the damage if he had not been influenced by the normal features of the part indicated by an X ray examination soon after the injury Radiographs taken following reduction of a traumatic dislocation of a joint may not show any departure from the normal for several weeks—the evidence provided by the

CHAPTER XXV

GRANULOMATA OF BONES

EVALUATION OF THE NEGATIVE RADIOLOGICAL REPORT

In patients with important items in their clinical history or those with obvious clinical signs and symptoms, X-ray examination often fails to show any departure from the normal. These cases are far in excess of those which show important, not necessarily spectacular radiographic evidence and yet appear clinically to be sound. Such absence of correlation has been responsible *for the unreasonable condemnation* of the radiologist and radiographs by men who have not had the requisite training in clinical or radiographic work, for such men by the nature of their training avoid rather than seek co-operation; they have been taught on the basis of cases with well-established spectacular signs. Most of the radiographs shown to students at lectures and demonstrations or illustrating text-books, are of fully developed characteristic lesions; from the very *nature of things, illustrations indicating the earliest departure from the normal* could not be used for teaching purposes, except for the person who has set out to study the problem and specialise. The early signs can only be appreciated by routine daily examinations, most of which show structures which are within the normal limits. Even the radiological features of the normal tissues require considerable study, since no two are exactly alike, the limits of the range show marked differences. Accepting this, it is necessary to realise that the early signs of departure from the normal may even evade the detection of the expert. But it is he who should investigate and explain his findings, either to the clinician who seeks his co-operation, or to students, *e.g.*, during a ward class.

There is no ancillary service to medical and surgical science which is so much abused as radiology. An account of the more common abuses have been published elsewhere. Because of the bad teaching of radiology to students there is a resultant failure to recognise what I have described as "the latent negative radiographic period," *i.e.*, that period which elapses between the onset of clinical signs and symptoms and the appearance of radiological evidence; and the "positive radiographic symptomless period," *i.e.*, that period after the disappearance of clinical signs and symptoms, and during which the radiograph still shows departure from the normal.

The Latent Negative Radiographic Period. The impression has been widely adopted that the onset of a lesion is immediately associated with the production of radiographic signs of such lesion. This is a fallacy which has been responsible for many errors in diagnosis and much delay in treatment, because the absence of such signs has been regarded as reliable evidence that the conditions suspected did not exist. Even though the clinical signs and symptoms persisted the negative radiological evidence obtained at the first examination has been allowed to dominate or confuse the outlook for a time dependent upon the rapidity of progress of the disease; in some cases weeks, in others a year or more; and when a second examination has been requested, often the result of the calling in of a further consultant, the radiographs show characteristic evidence of extensive damage or disease. This has occurred in many conditions, but more commonly following trauma and in tuberculosis and malignant disease of bone. In some cases, however, the latent negative radiographic period is so long that even a second or third X-ray examination after intervals of weeks or months has failed to reveal positive evidence, notably in cysticercosis, some cases of bone tuberculosis and secondary metastases of malignant disease in bone. It is most important that periodical X-ray

as has been shown, may not be recognisable during the active phase of their existence when the most important symptoms are caused but once calcified they produce radiographic evidence which will persist throughout the remainder of the patient's life usually unaccompanied by any symptoms. The same can be said of the calcified fibroid and the overlooked fœtus which is transformed into a lithopædion

Some inflammatory lesions leave no trace, but those which show calcification or abnormal ossification, such as osteomyelitis and tuberculosis, may persist as healed lesions always recognisable by radiography other cases exhibit periodic recrudescence In the early stage of recrudescence, although the clinical signs are prominent, the radiograph will not give any indication of anything but a healed lesion, *i.e.*, again there is a latent negative radiographic period and it is necessary to wait for some time before radiological evidence of the reactivity of the lesion can be obtained

Two sources of error are possible from this positive radiographic evidence The spectacular appearance of the healed lesion may be discovered accidentally during a routine examination, as in mass radiography of the chest or following radiography for an injury and be responsible for surgical interference or prolonged investigation, although the patient shows no signs or symptoms. On the other hand, the detection of radiological evidence of calcified or consolidated foci may cause the observer to regard the lesions as healed and to discount the symptoms of which the patient complains, particularly if the question of compensation in any form has to be considered, or if the recent radiographs show no change from others taken during the quiescent period

The latent negative radiographic period of reactivity of an old lesion or of a secondary or tertiary infection may be imposed on a patient whose radiographs show evidence of an old lesion, *i.e.*, one showing the positive radiographic symptomless period. There is always a danger that the radiographic evidence of an old healed lesion will be allowed to dominate the treatment although the patient may be showing clinical signs and symptoms. For instance, although the X ray examination may show calcified cysticerci this is no evidence that a more recent infestation has not occurred The radiographs at the site of a recent injury may show for a time only evidence of an old lesion—I have observed this in a patient who had sustained a recent injury to the wrist. The radiograph showed an old ununited fracture of the scaphoid with rounding off of the fractured surfaces but no signs of recent injury It was only after a month that further radiographs showed that the recent injury had in fact rendered one fragment avascular and that considerable osteoporosis had been produced in the interval (see Figs. 08 A and B) The radiographs of bones which have been involved in osteomyelitis may show only evidence of the old disease for a week or so after the patient has exhibited clinical evidence of a recrudescence nor must it be forgotten that malignant metaplasia may occur in any of the lesions of the osseous dystrophies, simple cysts and tumours, or the sites of old injuries. For a time the radiographs will show but the evidence of the old lesions although careful examination of the clinical evidence may indicate that a change has taken place It is necessary to wait for a variable period depending upon the rapidity of the malignant growth, for the radiological evidence to indicate that disintegration or other change is in progress. But it is in tuberculosis of the lungs that faulty interpretation of the radiographic appearances is most often met with. This is a serious matter because it is now common practice to dispense with investigations of the clinical history and conditions and depend upon the radiograph for evidence of active disease and if it is not present to ignore what appears to be old calcified foci indeed the directors of official mass radiographic units are told by the Ministry's advisers to ignore these calcified lesions. As any patient with a calcified primary focus or a post primary calcified lesion may at any time become reinfected and for a time fail to show radiographic evidence of this

radiograph after several months, may escape detection. Consequently the patient may be encouraged or even compelled to use the joint. Because the trauma was severe and yet the X-ray appearances normal, the patient may be told that exercise and still more exercise is the best form of treatment. As most injured persons are anxious to get back to their duties, particularly when they have confidence in the surgeon, who warns them that some pain and disability must be expected whilst persisting in duties which are deemed essential by the surgeon for their recovery work is continued even for a year or more in spite of much pain and increasing disability When at last their confidence in the surgeon or rehabilitation officer breaks down and they seek other advice it may be found that the radiographs now show that the joint is disintegrated and beyond any hope of recovery Rest of the joint giving pain or disability with more careful radiological control at shorter periods to detect evidence of avascularity is the only way to prevent such disasters. Avascularity of the bone can be recognised radiologically by its relative density only when sufficient time has elapsed with the limb immobilised to permit of decalcification of the normal bone.

The destruction of the vascular supply to a fragment of bone results in avascular necrosis of the fragment. Such dead bone will ultimately be reconstituted by a gradual growth of vessels into it but so long as any portion remains avascular it will induce hyperæmia of the part and plasticity of the adjacent bone. Consequently if the part is subject to function before complete reconstitution of the dead fragment, not only will the repair be delayed by repeated damage to the young vessels but pressure deformities of the plastic bone will develop and permanent disability will be caused It may take up to four years before the dead fragment is removed. Prompt removal of the dead fragment would result in more rapid consolidation but when the stability of the part will be impaired, particularly in a young person, the longer immobilisation would give the better ultimate result. Only occasionally do we see complete autolysis of an avascular fragment within a few weeks It has been seen to occur in the femoral capital epiphysis following osteomyelitis

It may take upwards of several months before radiographs give supporting evidence of *tuberculosis* or *secondary carcinoma of bone* The diagnosis has been missed on many occasions because the negative radiological evidence at one or perhaps two examinations has been regarded as excluding these conditions (See Fig. 497 and associated clinical notes.)

There are many other conditions which could be instanced in which there is a long latent negative radiographic period with ultimately definite and characteristic radiological evidence. To wait until the latter is present before adopting remedial measures is to rob the patient of the best chances of recovery Too often, even in conditions in which the latent period is but a few weeks, because a radiograph taken in the early days of a patient with prominent symptoms is reported as negative, this evidence is taken as excluding the suspected condition and, although the clinical signs and symptoms persist or are aggravated, the call for a second X ray examination is delayed well beyond the latent negative radiographic periods and when it is made the radiographs show well-established disease with considerable destruction of the bones often beyond the possibility of a good recovery

The Positive Radiographic Symptomless Period. This period may exist for but a few days after the disappearances of clinical signs and symptoms as in pneumonia, but in a number of conditions radiological evidence of past disease persists for the remainder of an apparently healthy life Generally speaking the less the destruction during the active phase the less the residual radiographic evidence Lesions which tend to calcify are those which show the most persistent radiographic evidence The cysts of animal parasites (cysticercus cellulosæ echinococci, trichina, filaria, dracunculus, schistosoma),

negative. The child was brought to him because a similar condition had developed in the other leg, but though the Wassermann reaction was negative the condition was cured by anti-syphilitic treatment.

Syphilitic changes in the bones of infants can best be demonstrated by radiographs of the knee and wrist joint areas, but in doubtful cases further radiographs to show the upper ends of the femur and humerus are advisable

The disease is indicated during the first month of life by an accretion of periosteal new bone around the shafts of one or more long bones, a localised area of erosion of the extremity of a diaphysis or an increase in the density of the diaphyseal extremities of these bones: in some cases by bilateral subperiosteal hæmorrhages with displacement of the linear dense extremity of the diaphysis.

The metaphyseal border of the diaphysis is more clearly defined than normal, and it is rendered more prominent by osteoporosis of the subjacent bone. This appearance is indicative of an osteochondritis and simulates the changes seen in scurvy at a later age, *i.e.*, the denser trummerfeldzone and the gerustmarkzone. With efficient medication these signs may largely disappear within one to two months.

As the lesion progresses the diaphyseal extremity increases in thickness, the zone of subjacent bone becomes more radiotranslucent, and an increased density appears in the cancellous bone adjoining this. The latter presents an irregular dentate surface to the radio-translucent zone, and the radiographs show two dense lines with rather irregular outlines at the ends of the diaphyses. These changes are due to proliferation of fibrous tissue and granulations, the dentate surface indicating that ossification is proceeding in this area only in tissue in juxtaposition to the vessels (see Figs. 80 E and 165)

The disorganisation which proceeds in the radiotranslucent zone permits of the ready displacement of the terminal sclerosed zone and the appearance of a fracture is so produced, as in scurvy

During the second month of life in the untreated cases the only indication may be a small area of destruction of the lateral surface of the extremity of a diaphysis which shows some degree of osteoporosis, the radiographs in other cases show in the expanded extremities of the diaphyses of the long bones some increase in the density of the cancellous structure except perhaps near to the cortex. As a result of this a more or less cone-shaped area of density is seen. Without the cortex evidence of a new periosteal layer of bone may now be seen The dense cancellous structure is separated from the growth cartilage by a thick semitransparent zone the borders of which are irregular Into this thickened osteoid metaphysis the denser cancellous bone may collapse and fragments may project beyond the lateral confines of the bones and may even appear to be mushroomed. Both extremities of the long bones may show these changes—some may escape the changes. The cancellous tissue throughout the shafts in some cases shows ill-defined areas of increased density

Not infrequently one sees rarefied areas suggesting erosion at the corner of the base of this cone. As the child advances into its third month the prominence of these signs fades The cancellous bone farther up the shaft now shows increased density and the formation of periosteal bone of a dense character is accelerated.

If the disease proceeds unchecked this periosteal new bone may ultimately form a broad involucrum within which the outline of the original shaft can be seen. This appearance of osteoperiostitis may be seen at any age after the end of the third month (see Fig 92, A).

This condition of osteoperiostitis may continue to progress, the involved bone becoming more irregular in outline and density In the lower extremity particularly the tibia, the involved bone bends with the superincumbent weight and the characteristic

re-infection, *i.e.*, the latent negative radiographic period of reinfection such advice may well lead to such delay in treatment that recovery may be impossible and in the interval the unsuspected disease may be disseminated, the more readily because at a radiographic examination the patient was declared free from infection

GRANULOMA OF BONE

The *proliferation of reticulo-endothelial cells in bone with the production* of granuloma-like masses a reticulo-endotheliosis is not a specific reaction. It can develop from stimuli of various kinds yet the clinical, histological and radiographic features have something in common. Any bacterial invasion may cause it and the granulomata and symptoms produced by pathogenic cocci the typhoid group of bacilli tubercle bacilli, the organisms of syphilis or even malaria, the mycetes the lesions in aleukæmic leukæmia lipoid and lymphogranulomatosis and even the isolated or multiple foci in certain sarcomata myelomatosis or carcinomatosis bear a resemblance which calls for serious consideration in arriving at a diagnosis. The investigation must include an examination of the number and nature of the cells in the blood the nature of the organisms present; the reactions of the blood, particularly the Wassermann; the type and distribution of the lesions and the rate of their development and response to therapeutic agents. The signs and symptoms which develop depend upon the age and condition of the patient, the virulence of the infecting organism and the rapidity of growth, the extent and site of the lesions. In many cases the radiographic features, particularly the serial radiographic appearances, and the development of the lesions are sufficiently characteristic to permit of diagnosis, but no matter how characteristic the lesions appear to be, the possibility that some other agent is responsible must always be considered, particularly if the response to treatment is delayed or unusual. As the syphilitic lesions can simulate any of the others, and their response to treatment is so spectacular and apparently complete, the possibility of syphilis must first be excluded

SYPHILIS

(see Figs 80 E, 92 A and B 93 94 116 117 A and B 120 130 150, 165–171 280–284 413)

Syphilitic bone lesions may occur at any age They can counterfeit any bone lesion. For the purposes of classification the bone changes will be described as they are manifested by radiography in infancy in adolescence and in adult life Generally speaking, it may be said that while in infancy all the bones show changes, in adolescence though symmetry of distribution is frequently observed, the lesions are usually asymmetrical in extent and distribution, and finally in adult life the lesions are few and irregularly distributed These facts suggest an ephemeral character of the infantile lesions and may explain the reason why some authorities can report on radiographic changes in 25 per cent. of stillbirths, but in only 2 to 5 per cent. of children born alive and in occasional cases only in children over 6 months of age The complete restoration of affected bones following efficient medication (see Figs. 92 A and B) must also be taken into account The radiographic appearances change with medication.

Bone Changes in Infancy (see also Cranio Tabes pp 10 20 and Prematurity p. 4). The significance of the radiographic appearances of bone syphilis in infants must be appreciated, for it is frequently the only evidence on which the diagnosis can be made A negative Wassermann reaction is not conclusive proof that the child is not suffering from syphilis.

Vaughan Dunn has reported the case of a child whose leg had been amputated because of a chronic inflammatory lesion of the os calcis, the Wassermann reaction being

mities of the diaphyses they appeared normal—the increased length of the affected bones persisted. The patients had had mercury (see Figs 92, A and B)

Shattock has described a gummatous osteitis of the fibula in a child 4 years of age

Lingeman has published radiographs showing a gumma of the upper end of the tibia in a boy of 8 years.

The skull of the infant, most commonly in the frontal and parietal areas, may show Parrot's nodes, and radiographs of these lesions show the appearance of syphilitic osteitis in the shape of irregular areas of osteoporosis involving the inner or outer tables

Syphilitic osteitis of the base of the nasal bone and maxilla is not infrequent in such children, but it is rare to receive a request for radiographs of this area. The characteristic teeth described by Hutchinson may be present.

Syphilitic dactylitis is said by *Holt* to occur in children under 1 year of age, and to attack the metacarpals and metatarsals more frequently than the phalanges

Vogt[2] recorded it to be present in 10 per cent. of 104 cases

An osteoporotic type of syphilis also occurs in infancy Attention is drawn to it by the fragility of the bones, and it may be mistaken for osteogenesis imperfecta. Radiographs of the whole skeleton will, however furnish evidence of the changes of syphilis in the shape of a sub-periosteal erosion at the extremities of the diaphyses, subperiosteal hæmorrhages or localised periosteal thickening Such appearances were seen by the author in the radiograph of a child of 14 months. This child also showed bilateral cervical coxa vara and very slender rarefied bones (see Fig 281).

In the case of the patient whose radiograph is shown in Fig 280 the syphilitic lesion in the one femur led to the development of unilateral coxa vara.—an appearance which simulated that of infantile coxa vara, but all evidence of active disease of the bone had disappeared.

In a girl of 12 years following an injury a swelling developed. A persistent sinus developed after exploration. Radiographs showed irregular decalcification of the shaft and thickening of the cortex by multiple linear accretions resembling Ewing's sarcoma. Later progressive periosteal reaction and localised disintegration occurred Five years later the Wassermann was found to be positive. The lesion responded well to anti-syphilitic treatment.

Radiographs illustrating syphilitic-bone disease of infants are to be found in the papers by *Joseph* and *Lesser Klaften* and *Priesel, Mouchet,*[2] *Pehu, Chassard* and *Ensélme Pendergrass* and *Bromer* and *McLean*

The histological findings are described in the papers by *Eardley Holland Wegner* and *Turnbull.*

Glaume in a paper on the ætiology and pathogenesis of achondroplasia, suggests syphilis as a possible cause. He illustrates his case with details of a child aged 30 months. The blood of the child and its parents gave a positive Wassermann reaction.

Cassar and *Jaubert de Beaujeu* consider that heredosyphilis was the causative factor in a case of myositis ossificans. They published radiographs of a child aged 2 years, showing the typical appearances. The ossified bands disappeared after 3 months treatment, though the muscle stiffness persisted.

Bone Lesions in Adolescence. Bone lesions in adolescence may develop as chronic extensions of the lesions which have been described as occurring in infancy Isolated bones may show the changes referred to as osteochondritis (see Fig 120). They respond to medication.

They appear radiographically as osteoperiostitis, as in sabre tibia, or as gummata, in which there is a localised sclerosis with a relatively small central area of rarefaction The development of these localised lesions is often seen to follow trauma of the part.

appearance of sabre tibia is produced (see Fig 168) A similar appearance of the tibia has been recorded by *Duncan White in yaws.*

The epiphysis in the first and second months may show an increased central density with an irregular ill-defined periphery but in some cases central rarefaction and peripheral sclerosis have been described. The different appearances of the diaphyseal extremities of the bones in syphilis and rickets have been ascribed as due to differences in vascularity *It is stated that* in rickets there is increased vascularity therefore the bones are osteoporotic, whereas in syphilis there is a diminished vascularity which results in sclerosis. If this theory is correct we must assume that in the osteoporotic type of syphilis some factor induces increased vascularity and that ultra violet radiation reduces the blood supply to rachitic lesions.

At the end of a year during which treatment has been given the limb bones of infants which exhibited all the signs of syphilitic osteochondritis may appear to be almost normal, in other cases the shafts at the junction of the middle and lower thirds may show coarse cancellous tissue with ill-defined and incomplete transverse lines. One or other bone may show an area of localised destruction with some increased density of its irregular periphery and an accretion of periosteal new bone spreading along the shaft from near the lesion.

One or more bones of the carpus or tarsus may show an area of syphilitic osteochondritis. This is to be recognised by a change in the cancellous structure The area affected has a fairly well-defined border which is sclerosed within, the bone is of increased density its cancellous structure is destroyed or obscured by the increased calcium deposit.

After 3 years, changes in the metaphyseal extremity of the diaphyses may again attract attention on account of the irregular sclerosis, as in Figs. 166 and 167 *Little or no change may be present at this stage in the metaphyseal border of the epiphyses,* but if such a case is radiographed at intervals during the next few years, the depth of the irregularly sclerosed zone in the diaphysis diminishes but its density and definition increase with the production of similar changes on the opposing surface of the epiphysis, as in the cases illustrated by *Contamin* and *Pouzet.* Gummata may be indicated by *localised sclerosis and thickening containing a relatively small rounded area of bone destruction.*

A brother and sister (patients of the author) aged 7 and 6 years, showed asymmetrical syphilitic lesions. Radiographs taken in 1937 showed :

Boy aged 7 A gumma of the middle one-third of the left tibia. Compared with the right tibia the shaft of the left was generally of a more robust build—half the thickness again of the right : at the junction of its middle and upper one-third there was a spindle-shaped area of dense bone on the anterior aspect—actually this reaction appeared to involve the anterior cortex on the entire length of the shaft. In the thickest section of the dense bone where it involved three-quarters of the thickness of the shaft a suggestion of breaking down of the centre is given by an ill-defined but irregular area of diminished density around this In addition to the general thickening of the bone a spindle-shaped periosteal accretion of new bone can be recognised—a gumma

Girl, aged 6. Syphilitic osteomyelitis of the right ulna. This is more than double the thickness of the left ulna. It is of much greater density and except at its distal end has lost the detail of cancellous tissue The proximal end is irregular in outline and density The shaft has an involucrum which is broken up in the middle third and except at the distal third does not reveal the detail of the original shaft. The left humerus is also much thickened but the periphery is regular and the condition does not appear to be so active as in the ulna. No other lesions could be detected in any other part of the skeleton The affected ulna and tibia of the two patients were longer than the unaffected—this persisted after healing Radiographs taken on 20 8 41 showed that the lesions related above had completely disappeared and the affected bones were indistinguishable from the unaffected and but for some condensation at the extre-

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and may have a regular periphery with a small rounded area of radiotransparency on a plane with the original periosteum Such lesions are probably subperiosteal gummata —they resemble the chronic subperiosteal abscesses due to other organisms. In some cases the thick periosteal new bone has a coarse fibrous structure with a crenated periphery In some cases the localised periosteal reaction may be indicated by multiple linear accretions which with the clinical appearance of a tumour may be interpreted as sarcoma (see Figs. 117 A and B). The irregular surface goes within a few months of efficient medication (see Fig 170 also effect of arsenic and bismuth)

(3) General increase in the bulk of the bone which has denser islands somewhat resembling the fossils in Derbyshire stone at which sites the bone may be slightly expanded and its medulla obliterated The periosteal border may be smooth though undulatory In other cases it may be massive, irregular and sclerosed as in Figs. 170–171

(4) General osteoporosis of a bone with one or more areas of destruction and absorption. Spontaneous fracture and absorption may occur In the early phase of development of the lesion there may be little sclerosis but in the more chronic lesions the periphery of the lesion is sclerosed and irregular Such lesions are found in Bejel (the endemic form of syphilis which occurs in the valley of the Euphrates)

(5) A chronic osteomyelitis involving the whole of the bone with destruction of the original cortex, marked expansion of the bone which is irregular in texture peripheral outline and density (see Fig 94).

Single or multiple osseous gummata may be discovered. The commonest site is probably the clavicle and radiographs of this bone may show that the whole bone is considerably thickened and sclerosed. Small central areas of destruction are usually to be seen, but sequestra are rare unless the lesion has been secondarily infected Marked reduction in the thickness and sclerosis follows antisyphilitic medication. When the gumma is situated within the medulla of a long bone it may stimulate excessive periosteal growth, and this may show on the radiograph striae which are perpendicular to the line of the periosteum. Such appearances have been interpreted as those of sarcomata, with disastrous results. They are to be distinguished by the fact that in the sarcomata this periosteal new growth is in the form of fine sharp, straight linear pallisade-like spicules, the length of which gradually diminishes until the normal periosteum is reached The spicules at the site of the primary growth focus are gradually absorbed so that the shaft on either side may present a so-called periosteal "cuff" (see Fig 188).

In the gummata the periosteal striations are not so clearly defined and regular and persist over the underlying gumma even when this has produced definite radiographic bone changes. They clear following efficient medication

The osteoporotic type is associated with general rarefaction of the bones and multiple areas of bone absorption which may be brought to light by the occurrence of spontaneous fractures.

The details of the following case illustrate the appearance which may be seen.

The patient a soldier aged 35 was sent for radiographic examination to ascertain the nature of a spontaneous fracture of the humerus The radiograph showed marked irregular osteoporosis of the shaft of the humerus the middle third of which had fractures through a zone of less density Further radiographs were taken which showed that the inner half of the clavicle on the opposite side had been completely decalcified, and only the outer half could be detected on the radiograph. The spine showed general osteoporosis also and radiographs at a later date after the administration of anti-syphilitic treatment indicated an increased density of the bones. The inner half of the clavicle did not assume a normal appearance and only an irregular narrow strip of bone bridged the gap between the sternum and the outer fragment The cervical spine which in the acute phase had been lacking in density and sharpness of outline became ankylosed and denser

A girl aged 14 years was referred to the author because of the radiographic appearance of her humerus which was said to resemble Ewing's sarcoma. The upper third of the humeral shaft showed multiple linear periosteal accretions with localised destruction and alteration of the cancellous pattern (see Fig 117 A). There was a history of a severe blow seven weeks previously The radiographic appearances suggested that the lesion had been produced by trauma and as this is a rare finding in sarcoma a chronic inflammatory lesion was suspected. The lesion began to show resolution on the administration of a course of sulphathiazole and after determining that she had a positive Wassermann specific medication brought complete resolution (see Fig 117 B)

In some cases, as in the one published by *Campbell*,[1] the gumma has the appearance of a bone cyst with a sclerosed wall. Gumma of the spine may present the radiographic appearance of tuberculous caries with a surrounding abscess, as in the case published by *Sinding Larsen*[2] This is probably very unusual, but that the two diseases may have an identical radiographic appearance should be appreciated

The affected vertebræ may collapse as the result of the destructive process, but its uneroded borders are usually sclerosed.

Radiographs of children with bilateral painless knee-joint effusions, first described by *Clutton*, may show irregular sclerosis of the adjacent metaphyseal borders of the femur and tibia as in Fig 167 Bilateral syphilitic osteochondritis is not an uncommon complication

Bilateral coxitis, in which the radiograph showed erosion or softening and deformity of the articular surface of the femoral heads has been seen in 4 cases. Definite consolidation of the bone followed the administration of mercury and potassium iodide, though in one case the articular surface of the femoral epiphysis appeared to be destroyed before the treatment began In another case, though the articular surface of the head reformed after a period of medication, 4 years after this treatment was dropped, destructive erosion of the articular surface again occurred.

Radiographs illustrating these syphilitic bone lesions are shown in Figs. 282 283.

The long bones of a limb with disturbance of its innervation (as in spina bifida, syringomyelia, etc.) may show either thickening of the compact tissue or much new periosteal bone at the site of injury and give the suspicion of syphilitic periostitis.

Autolysis of fragments of necrotic bone (sequestra, bone-grafts etc.) is a feature in syphilis

In the Adult. Syphilitic bone disease of the adult may be due to congenital infection which may not have been suspected until a gummatous osteitis has developed in the bone, usually at the site of an injury If the injury has fractured a long bone this may fail to unite and radiographs show an irregular sclerosis of the fractured extremities. Attempts to bridge the gap between the fragments with a bone graft are usually unsuccessful. Serial radiographs show a gradual absorption of the graft and absence of callus.

In the secondary stage of acquired syphilis the patient frequently complains of pain or tenderness of individual bones but radiographs do not, as a rule, show any definite bony changes Effusion into the joints may occur but the only abnormality shown in the radiographs of the joints is an increase in the joint space.

In the tertiary stage four distinct types of lesions may be seen

(1) A localised expansion of the bone which has a dense periphery and a central area of destruction—a gumma. When subperiosteal, a crater like lesion is present as in Fig 171

(2) Localised periostitis which may involve only one aspect of the bone—the medial aspect of the femur being the more common The new bone is dense and thick

The Arthropathies (Charcot's Joints) A careful study of a large group of cases by serial radiography during the development of these joints has indicated a sequence of changes which can be usefully described in four phases *i.e.*, (1) Hydroarthrosis (2) Disintegration, (3) Hypertrophy and (4) Atrophy Arthropathies are most frequently met with in both sexes in the age period 35–40 years but examples developing in the earlier and later years of life are occasionally seen. Any joint or false joint may show this sequence of changes. In the case of the knee and shoulder bilateral affections are not uncommon, but though examples of bilateral arthropathy of the hip ankle and elbow are seen, unilateral lesions are more frequent. More than one particular joint may be affected so we see the hip ankle and shoulder affected in the same way but usually the changes in the joints do not commence together unless of course they are initiated by the same trauma, consequently the changes denoting the earlier phases in the different affected joints do not correspond on the same day

(1) **Hydroarthrosis.** Effusion of fluid into a joint following relatively mild trauma should arouse the suspicion of an early arthropathy particularly if this is associated with little or no pain.

Radiographs at this phase will show a separation of the articular surfaces, an increase in the joint space and the thickness of the soft tissues surrounding the joint. The articular surfaces are usually regular and clearly defined, the sharpness of outline may appear to be even better than the normal for the detail of the cancellous bones seems to be obliterated by the deposition of calcium within the interstices rendering the bone of uniform and slightly greater density Such are the only changes which may be revealed at the first examination. Later a localised regular shallow scalloping of the socket of the ball-and-socket joint may be recognised and this may be associated with an equally regular wearing of the articular surface of the ball changes which are more readily appreciated because of the sharpness of the outline of the denser homogeneous bone. These clinical and radiographic signs may show little change for 2 to 3 years. By the end of this time a second phase of greater activity develops probably initiated by further trauma which is often unrecognised by the patient.

(2) **Disintegration.** Clinically this is denoted by impairment of the stability and function of the affected limb, an increased swelling of the soft tissues around and for some distance from the joint, a brawny œdema of these tissues, the skin over which has the discoloration suggesting contusion and extensive deep-seated hæmorrhage, yet, with all this, the patient has little or no pain. Because of the latter he may fail to seek medical attention for several weeks, the medical officer may fail to appreciate the significance of these signs. It is unusual to have a patient referred for radiographic examination within a month of the onset of such clinical signs, even though the patient be receiving institutional treatment for such conditions as tabes or syringomyelia and the above clinical signs are prominent and associated with a fracture-dislocation. In a number of cases these clinical signs have been regarded as suspicious of sarcoma. The radiographic picture during this phase is characteristic. The articulating bony surfaces show a progressive wearing down. The bounds of the socket are extended, the head of the ball is gradually worn away and the joint space is correspondingly increased If one likened the rough irregularity of the outline and appearance of the tuberculous joint to the appearance of erosion of a very rusty disused tool, one may liken the worn articular eminence in the neuropathic joint to the sharp outline of the well-worn tool which is in constant use. The density of the bones already described persists and the sharp outlines remain.

It may in the latter end of the phase be masked in part and appear somewhat irregular because concomitant with this wearing away of the articulating surfaces there

In another publication by the author[9] radiographs were published showing irregular and massive new bone deposits having a woolly margin along the whole extent of the lumbar vertebræ of a man with tertiary syphilis. In this form of syphilitic spondylitis, erosion and sclerosis of approximated surfaces is associated with dense massive new bone and in some cases lateral displacement of bodies at the apices of the curvatures. Fig. 284 shows marked thickening and sclerosis of the one side of the pelvis, with destruction of the articular surfaces of the acetabulum due to syphilitic osteitis.

Syphilitic Dactylitis was seen in a man of 37. There was a spindle-shaped swelling of the finger with scalloped erosion of the neck of the proximal phalanx and an area of cancellous destruction in the base of the middle phalanx.

Lesions simulating those of syphilis have been found to have the histological features of *xanthomatosis*.

Radiographs illustrating further lesions can be seen in the papers by *Newmark*, *Steinbrinck*, *Pendergrass*, *Gilman* and *Castleton* and *Rost*.

Effect of Arsenic and Bismuth. In some cases of syphilis which have been on prolonged arsenic and bismuth medication the bones may take on an increased density which may be mistaken for the osteolithic form of Paget's disease or even diffuse carcinomatosis from prostatic, stomach or œsophageal primaries. In one case, a woman aged 59, there was a history of syphilis treated with arsenic (mainly trivalent) and bismuth over a period of more than 12 years. Radiographs of the clavicles, scapulæ, ribs and vertebræ showed an increase in the density of the trabeculæ. The cancellous tissue was coarse and dense, in places such as the spine, scapulæ, ribs, sacrum and pelvis, rather resembling Paget's disease, but none of the bones showed the pressure deformities of plastic bone as in Paget's disease. The vertebral bodies in the lumbar area showed an increased ill-defined density within. The skull was thickened and its structure detail obliterated. The bones of the extremities did not show any marked changes, though the humeri, femora and tibiæ had lost to some extent the intricate architecture of the cancellous tissue and the cortex appeared to be a little thicker—the cortex medullary boundary was ill-defined—the one was blurred into the other—but the sub-periosteal border was clearly defined. The cancellous interstices were not packed as in fluorosis. *Dr. J. V. Sparks* kindly sent me the skeletal radiographs of two patients showing this reaction.

CHANGES IN BONES, JOINTS AND SOFT TISSUES ASSOCIATED WITH DISEASE OR INJURY OF THE CENTRAL NERVOUS SYSTEM

(Figs. 17, 48 A, 49, 72, 73, 118 A to C, 188, 189, 190, 200, 210 A and B, 243, 285, 286, 287, 310 A and B, 311 A and B, 399, 400 and 405)

Besides the arthropathies, described by *Charcot*, found in association with tabes dorsalis, syringomyelia, spina bifida, myelitis, post-encephalitis, paraplegia, injuries to the posterior nerve roots and other affections of the central nervous system, certain other changes, usually of much less importance, may be seen to follow injury to the central nervous system, notably the so-called localised myositis ossificans and ectopic bone formation.

These joint lesions may be single, multiple or bilateral, such as both shoulders, elbows, hips, knees, ankles, subastragaloid, mid tarsal or great toe joints. The bilateral distribution, particularly of the smaller joints, indicates an unusual symmetry of lesions to be due to trauma or precise central localisation. Thus in a man of 23 years there was disintegration of the head of the astragalus and the navicular on both sides, typical neurotrophic joints though the Wassermann was negative and no lesion could be detected in the central nervous system.

any appreciable radiographic alteration from the normal prior to the development of the signs of the neuropathic joint, fractures, sometimes comminuted are not infrequent, particularly in the intertrochanteric area of the involved femur and the lower ends of the tibia and fibula. The impression is given from the examination of affected patients that these fractures are caused by trauma which would not fracture normal bone, but it is probable that, in addition, it is the lack of sensation and the reflex protective influence of the muscles which permits forces to act on the bones forces which the muscles would normally have spared these bones Such fractures often precede the development of the neuropathic changes already described by as long as 2 or 3 years, or they may initiate and become the site of them. Thus a woman of 26 years sustained fractures of the four metatarsals of the left foot, as the result of relative slight trauma, which were associated with much callus and consolidated within six months. A year later she developed neuropathic changes in the left mid tarsal joint. At this time she sustained a fracture of the rami of the left pubic bone when she was one month pregnant. This fracture was also associated with much callus and consolidated before the infant was born, but the left hip joint now showed the early changes of a neuropathic joint which underwent considerable destruction during the next year A neuropathic joint also developed in the right mid tarsal joint at the same time. Neuropathic changes are sometimes seen in the false joint at the side of an ununited fracture Attempts to secure union of such joints in extra-capsular fracture of the neck of the femur by the insertion of a Smith-Petersen pin have been unsuccessful. The bone around the pins was absorbed and the pins came away the fractured extremities of the bone presenting the clear worn surfaces of the neuropathic joint. The author has published the serial radiographs of a case.[41]

In the infant with paralysis associated with spina bifida effusion into joints and multiple fractures may occur without any known trauma. Ossification may be seen in the hæmatomata which envelop the fracture sites (see Fig 494).

Localised Myositis Ossificans. In a small percentage of patients at the site of contusions, more commonly in the region of the femoral shaft and lateral aspect of the ilium, a sequence of changes, recognisable on radiographs, occur which bear a close resemblance to those seen in the soft tissues around a neuropathic joint So close is the resemblance that one is forced to believe that some common factor is in operation in both, *i.e.*, a lesion of the central nervous system. In this condition the patient may complain of some limitation of the movement of a limb and discomfort over a hard swelling of the part the skin of which may be reddened and tender If recent, some sign of discoloration of the skin may be seen, but often the patient cannot remember having received any injury to the part. Radiographs of the part will furnish a clue to the nature of the lesion. The earliest recognisable feature which is not visible for 3–4 weeks *after* the trauma, is the deposition of flocculent calcium near the bone in the region of the tumour As the amount of calcium deposited in the soft tissue increases during the following month the density renders the lesion more obvious This calcium appears to be taken from the adjacent bone for this shows a localised but ill-defined area of decalcification of its cortex. During the second month organisation of the calcium occurs and evidence of this is seen in its frayed cotton-wool appearance *It is the* association of these clinical and radiographic features which have led to the erroneous interpretations of sarcoma and the subsequent surgical disasters for in this active phase by surgical interference not only is the development of ectopic bone likely to be extended with increase in the period of invalidism of the patient, but the materi removed at biopsy if this precedes amputation, may show a *histological stru* indistinguishable from sarcoma by the most authoritative pathologists. Th

is a deposition of flocculent calcium within and without the capsule, and often extending along the humeral or femoral shafts as far as the lower thirds Other calcium deposits of a similar nature may be deposited in the more distal parts of the extremity This phase usually lasts from 3–6 months after which time the joint enters into its third phase.

In some cases particularly in young people disintegration of the metaphysis occurs the epiphysis may be fragmented while the end of the diaphysis may be thickened and bear multiple periosteal accretions which with the clinical evidence of a tumour may be mistaken for sarcoma (see Figs 210 A and 493)

Hypertrophy Clinically the affected joint appears to be swollen but the swelling now indicates bony rather than soft tissue changes The oedema and skin discoloration has gone or has largely diminished. An undue mobility of the joint and a diminished stability and strength of the limb may be indicated. The radiographs indicate that the calcium deposits are undergoing organisation. Much of the intracapsular calcium will have been utilised in building up extensions of the joint socket which may now appear to be twice or three times the capacity of the normal. The walls of the extended sockets are dense and massive. In the case of the acetabulum the socket is extended upwards and outwards to form a larger roof for the joint, in the glenoid it is mostly the inferior aspect which is extended but in some joints such as the sterno-clavicular the new bone is distributed regularly around a deep cup-shaped socket in the sternum. Much of the extra-capsular calcium deposits will be completely absorbed and no trace left other deposits, particularly those lying along the shafts of the bone will show organisation into irregular masses of new bone. Isolated deposits may be organised into ossicles of ectopic bone. Regarding the latter it is interesting to note that in a tabetic whom I described with Paget's disease a neuropathic hip joint developed which was associated with the development of four ectopic ossicles each about ½ inch in size in the region of the Tendo Achilles. Two of these were surgically extracted and on histological examination were proved to have the characters of Paget's bone (see Figs. 190 and 278)

The duration of this phase is not readily determined but it appears to be about 3–5 years. *At the end of this time the characters of the final phase will begin to show*

Atrophy As a result of the disorganisation and diminished stability of the joint it begins to show the atrophy of disuse. The muscles and soft tissues, as well as the underlying bones, diminish in size and the swelling previously so prominent, gradually disappears and the area flattens out. The limb becomes increasingly weaker

The radiographs show diminution of the extent, thickness and density of the expanded socket and still further absorption and diminished density of the extremity of the long bone A cancellous structure of the bone reappears and the articulating surfaces may now look irregular and frayed. Much of the extra-capsular ectopic bone will appear to be undergoing dissolution

Sequence not Repeated. It is interesting to note that this series of changes from the hydroarthrosis, acute wearing away of the articulating bony surfaces, the deposition of calcium and its subsequent organisation and development of ectopic bone appears to take place only once in the history of the neuropathic joint. The changes appear to be initiated by some trigger response which is not repeated in that particular joint.

It was seen that further trauma to the affected tissues during the active phase causes an extension of the changes, but as I have previously illustrated, resection of the mature ectopic bone is not followed by a recurrence of the changes but by absorption of the remnants which are now relieved of function abstracted from the adjacent normal skeleton. In the tabetic the development of these changes may not occur for 25–30 years after the date of infection (see also p 620)

Fractures. Though the bones of the patient with tabes or syringomelia do not show

the radiographs of the area revealed no abnormality but 20 days later further radiographs showed large woolly deposits of calcium in and around the elbow joint 5 weeks after this radiographs showed that the calcium has been organised and was now represented by smaller well-defined bosses of ectopic bone

In a case of spastic diplegia round ossicles of ectopic bone were found near the inferior border of the patella (bilateral).

Atrophy of the bones of the foot is frequently seen in association with central nerve lesions. It is seen in leprosy and to an even greater account in association with some cases of psoriasis. The most remarkable case of atrophy of all the extremities is that published by *H Cohen* unfortunately no explanation was given to account for the spider like appearance of all the bones of the arms and legs.

Shands[2] has classified the neuropathies of the bones and joints as follows

(1) Tabes dorsalis (occurs in 3 4 per cent. of cases)

(2) Syringomyelia (occurs in 10·4 per cent. of cases).

(3) Following lesions of the peripheral nerves, (*a*) injury (*b*) peripheral neuritis, (*c*) leprosy

(4) Following lesions of the spinal cord, (*a*) injury (*b*) congenital malformation, (*c*) tumours, (*d*) tuberculosis, (*e*) acute myelitis, (*f*) anterior poliomyelitis.

(5) Following lesions of the cerebrum, (*a*) dementia paralytica, (*b*) hemiplegia following cerebral hæmorrhage.

He estimates that 75 per cent. of the tabetic arthropathies occur in the lower extremities, while in syringomyelia 80 per cent. occur in the upper extremity Further radiographs, with details of the cases, are to be obtained in the papers by *Ghormley Higgs E. J S King Loewenberg Detlev* and *Wehmer McCalla* and *Warren Ross Worster Drought* and the author[39 and 41]

TUBERCULOSIS

(Figs 62, A, B C, D 71 90 91 97 115 146 147 172, 204 A and B 205 206 275–278 401–408)

A radiograph should be taken of the chest of every patient who appears to have a tuberculous lesion of a bone or joint it will often supply confirmatory evidence but even with active tuberculous lesions of the bones and joints it is common to find that the chest lesions appear to be old—there is calcification in the foci, perhaps definite increase in the lung striæ of a lobe or radiating from the root but not the cavitation or caseating broncho-pneumonic type of lesion this feature may be associated with bovine organisms.

The radiographic appearances shown in joint tuberculosis have been described in the chapters dealing with the anatomical distribution of diseases. While it may be said that tuberculosis of the bone can exist before it is possible to detect any bony changes on the radiograph it is equally true that a tuberculous lesion will sooner or later produce changes which can be detected on the radiograph. It should be appreciated, therefore, that a negative radiographic report in the early days of the disease is not conclusive proof of normality two or three further radiographs should be taken at intervals of 2 or 3 weeks if the symptoms persist (see Figs. 277 A and B).

If the disease is present an indication of bone irregularity will appear and once it has appeared, the bone will show evidence that it has existed, sometimes for the remainder of the life Repeated negative radiographic findings over a period of 3 months will usually exclude a tuberculous bone lesion. But osteoporosis of the part may be the only indication for a year or more.

The importance of these findings is indicated by the details of the following which came under the author s notice

that it is rare for sarcoma to develop at the site of a healing fracture should check the urge for biopsy with its great risk of erroneous interpretation. If the affected limb is immobilised the calcium will ultimately be organised into ectopic bone and the adjacent cortex will be recalcified and receive accretions which connect the boss of the new bone by an isthmus of varying breadth. For a year or more this ectopic bone will be of greater density than the bone to which it is applied, particularly if it impairs the function of the latter but gradually it will be absorbed, only a localised thickening of the cortex remaining to indicate the site

The timetable of the sequence of the radiographic appearances in myositis ossificans is of considerable significance—it may be upset by the damage of biopsy Thus *Geschickter and Copeland* record a case of sarcoma in a man aged 28 years, who after injury to the upper arm, gradually developed a swelling Radiographs showed some new bone at the site—this was thought to have followed stripping of the periosteum at the insertion of the deltoid by indirect violence the month before. Seven months after the mass was larger and felt bony A further year after the mass showed more rapid development. A large mass was exposed at operation. Periosteal and cortical bone was curetted away Several pathologists reported that the histological material showed no evidence of malignant disease and the diagnosis of myositis ossificans was made Two months later radium irradiation was tried but the growth increased in size and fixed the shoulder joint. The upper extremity was amputated. There was no recurrence in 18 months but the patient died of metastasis 6 years later Even from material removed at autopsy it was reported that there was no evidence of malignancy It is possible that the course and treatment of this case was modified or dictated by the biopsy findings.

Localised myositis ossificans is seen in a very small percentage of patients who have suffered contusions even in the areas in which this lesion is most common The theory that this ectopic bone formation is associated with a lesion of the central nervous system, sometimes but a transient lesion associated with hæmorrhage and vascular disturbance produced by the trauma, is supported by the radiographic appearances in a number of cases with known lesions of the central nervous system. Thus in a child with spastic hemiplegia the development of localised myositis ossificans was observed to follow tenotomy The new bone bridged the gap between the ilium and the great trochanter It became denser than the normal bones, which, with diminished function, were partially decalcified. Resection of the mature ectopic bone restored function to the bones, recalcification began and the remnants of ectopic bone were absorbed (see Figs. 311 A and B)

A male patient, aged 48 years, had a blow on the back of the neck which produced complete flaccid quadriplegia and retention of urine but no sensory loss. The lesion was regarded as a hæmatomyelia. There was no radiographic evidence of injury to the cervical spine Partial recovery occurred during the first week beginning in the legs. After 14 days some power of movement was seen in the shoulders and arms. Two months later the elbow joints were found to be thickened and œdematous. By X-ray flocculent deposits of calcium were shown around both elbow joints. During the year this was gradually organised with the development of ectopic bone which in part was absorbed The outline of the articular surfaces was quite regular and the joint space was preserved One joint was excised and the articular surfaces were found to be intact. In several other cases of injury to the spine, including the cauda equina and proximal nerve trunks, the sequence of changes resulting in ectopic bone were seen in the region of the more distal joints and limbs. A shorter time factor possibly associated with a fleeting nerve injury is shown in these cases, as will be seen from the following history The patient sustained an injury to the region of the elbow joint and on this day

to the inclusion of conditions which appear to be but remotely connected with the group but to the recording of cases which belong to the group, as, for instance the case recorded as sarcoidosis by *J. Porter* as separate entities—consequently the student is somewhat confused.

Clinically it is impossible to separate them, so wide is the range from an acute disease leading to a rapidly fatal progressive secondary anaemia, to one with slowly developing localised lesions which ultimately completely resolve.

For the most part they develop sporadically in infants from birth to 3 years of age a few in later years. One or two cases may be seen in several geographical areas in the course of a year with perhaps no sign of a case during an interval of 10–15 years, either locally or recorded in the literature

The features which attract attention may be a tumour on the head with a palpable defect in the underlying skull exophthalmos diabetes insipidus a progressive secondary anaemia without perhaps any abnormality in the leucocyte count, hepatosplenomegaly enlarged lymph-glands, a bilateral otorrhoea, a nasal discharge, spontaneous fracture of one or more vertebræ or proximal end of the femur or humerus with a moderate fever sometimes preceded by a seborrhoeic dermatitis or later developing a purpuric rash.

Histological examination of material derived from a lesion, be it bone, spleen liver thymus, glands, lung or skin shows a proliferation of the cells of the reticulo-endothelial system but may or may not show the presence of foam cells To that group of cases which do not show foam cells, *i.e.*, the non-lipoid granulomata, but which present the features indicated in the preceding paragraph, the term Letterer-Siwe's disease has been given.

These cases of unknown ætiology usually run an acute course in which they appear to exhibit a hæmorrhagic diathesis and end fatally A localised granuloma may develop at the site of a known trauma. The clinical findings in some cases arouse the suspicion of an infective process *Wallgren*, who reported two cases and analysed those already recorded, has stated "I think it would be difficult to find a single case of non-lipoid reticulo-endotheliosis in which it can be proved for certain that no infection was present."

A number of cases have been recorded which present similar clinical, radiographic and histological appearances with the addition of marked eosinophilia as eosinophilic granulomatosis. *Green* and *Farber* have recorded ten such cases from all of which material was removed for biopsy *Lichtenstein* and *Jaffe* recorded an eosinophilia of from 4 to 10 per cent. in their cases. Certain isolated simple lesions of bone have also been recorded as solitary eosinophil granulomata with perhaps little beyond the presence of eosinophils to support the diagnosis.

These lesions, which have been recorded more frequently in young people in the vicinity of the growing ends of bones, have the radiographic appearances of localised destructive inflammatory foci. The segment of bone involved may be disintegrated entirely or only a segment of the cortex and its adjacent cancellous tissue may be destroyed. Some of the lesions described have been well defined, others had a diffuse periphery Some periosteal new bone may be present on the adjacent cortex. Such appearances occur in tuberculous, syphilitic and septic foci and in the lesions due to the typhoid group of organisms, but the one feature on which stress is now being placed is the large eosinophil content. Histologically there is localised destruction of compact and cancellous tissue by granulations. Two types of cell have been described (*a*) eosinophil leucocytes which, packed together with little or no stroma, when stained produce bright red patches in the section (*b*) mononuclear histiocytes large pale staining cells which may show mitotic figures.

In the spine isolated vertebral bodies may show collapse as in Calvé's vertebra plana and in the dorsal region in the early stage a paraspinal abscess-like lesion may be recognised as a fusiform opacity by the lateral displacement of the adjacent medial border of the transparent lung. When resolution takes place this paraspinal lesion disappears, the included discs show no evidence of damage and the affected bodies are gradually rebuilt by peripheral growth as in osteochondritis, and after a few years the only indication of the lesion may be a relative diminution of their depth.

The radiographs, Figs. 480–482 are taken from a case of a boy aged 3. Previous to being seen by the author the radiographic appearances of the pelvis and upper femora had been regarded as those of multiple tuberculous foci. Their multiplicity and appearance suggested a lipoid granulomatosis and radiographs of the skeleton revealed the typical Schüller map-like skull and multiple lesions involving the bones at the shoulder and hip-joints, pelvis and the vertebral column. Several of the lumbar bodies were compressed. The lesions responded well to X radiation as shown in Fig. 480 A and B). Unfortunately the child developed the clinical signs of nasal diphtheria and later mumps but in November 1937 he appears to be in good health, none of the holes can be felt in the skull, and the other skeletal lesions have consolidated. He had no definite exophthalmos and no polydypsia, polyuria hepato- or splenomegaly. A biopsy was performed at another hospital but no foam cells were detected. The case of *Fawcett's* recorded on p. 415 has other interesting features.

A case with similar lesions was described by *J. Posner* as sarcoidosis. The patient a child of 2 years, had multiple foci in the skull and long bones, diabetes insipidus and

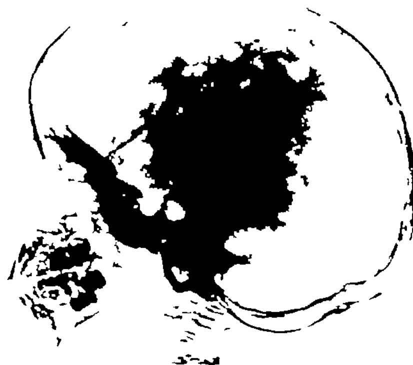


Fig. 480 A. Lipoid granulomatosis (15.3.40). See Figs. 479, 480B, 481, 482.

There are no foam cells. There may be localised tenderness, redness and swelling over the lesion but as a rule there is no increase in the temperature or pulse rate—in fact, no evidence of any generalised or visceral disturbances. No abnormal blood or urine findings The lesion is eradicated by resection or even thorough curettage A number have been treated by X radiation and completely resolved. Some appear to have resolved spontaneously

Certain cases which have been described as sarcoidosis, sarcomatosis, endothelioma, tuberose sclerosis and lymphogranuloma (Hodgkins) myelomatous and carcinomatosis may well belong to this group

The radiographic appearances are spectacular in some cases. One or multiple rounded defects may be seen in the skull of varying sizes as if decalcified by diffusion from localised deposits of acid The surrounding bone in the typical case of xanthomatosis also appears to be undergoing a general gradual solution —it shows no sign of protective reaction around the focal lesion, *i.e.*, increased density such as one sees in some cases of sepsis, tubercle or syphilis The circumscribed decalcified areas gradually enlarge and may become contiguous or merge until little bone remains to be seen in the skull. One or all of the accessory nasal sinuses or mastoid cells may be found to be destroyed in those cases with a fœtid discharge from the nose or ears. The teeth may be lost in alveolar destruction Some destruction may be seen in the orbits in those cases with protrusion of the eyeballs the latter may be destroyed. Destruction of the walls of the sella may be seen in cases with polydypsia and polyuria. All these radiographic and clinical features may be present without any other radiographic abnormality of the skeleton—this is common in xanthomatosis. But in some cases multiple areas of *decalcification may be found in the skeleton of the* trunk, spine, pelvis, ribs and scapulæ and the proximal ends of the femora and humeri—it is rare for more distal bones to be affected. Fracture may have occurred through one of these and brought the infant for its first radiographic examination These skeletal lesions bear a close resemblance to those seen in some cases of tuberculosis, and indeed may be mistaken for the latter they are fairly sharply defined areas of destruction which may appear to show some *debris*—probably due to compression of the thinned walls of the lesions The multiplicity of the lesions in these proximal sites should arouse the suspicion of systemic granulomatosis. The isolated lesion may well confuse and lead to misinterpretation of the pathology for in some cases recorded none of the typical lesions have been shown in the skull. A feature about these lesions is that when healing does occur it is complete and the bone is so completely re-organised that it is indistinguishable from the normal This does not apply to the accessory nasal sinuses. In the case recorded by the author (see Fig 438) years after none of the sinuses have developed and the face appears diminutive, also the exophthalmos, polydypsia and polyuria have persisted though in a much milder form than when the condition was acute. It has not interfered with general skeletal growth. In the case of *Sosman s*, recorded by *Green* and *Farber* 6½ years after treatment the boy is a blind, mentally retarded dwarf with marked spasticity

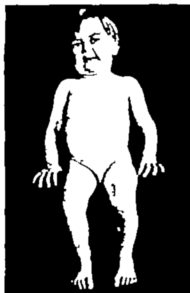


Fig 479 Lipoid granulomatosis (see Figs. 480–82).

increased hilar shadows with reticulation and mottling of the central lung fields. The appearances at biopsy suggested to the surgeon tuberculous lesions, and at post mortem multiple miliary lesions suggesting tubercle were seen in the bone marrow and various viscera.

The following case history and comments on a case which the author published [49]



Fig. 482. Lipoid granulomatosis (see Figs. 479–81). Note compression of upper lumbar bodies.



Fig. 483A. Disintegration of upper half of humerus. Note irregular surface and multiple linear periosteal accretions and large soft tissue tumour and shadows in lung fields (10/11/44).

has features which suggest that it might be of the nature of a lipoid granulomatosis :—

Case Record. A girl, aged 6 years, with a painful swelling over the right upper arm had been kept under observation at a children's hospital for some weeks, during which her temperature was normal except for a rise to 99° F. on four occasions; pulse-rate 90–100 per min. Blood count on October 17th, 1944, was : red cells 4,590,000 per c.mm. ; colour-index 0·96 ; Hb 90 per cent. ; platelets 286,666 per c.mm. ; haematocrit 36·2 per cent. ; mean cell volume 79 per cent. ; reticulocytes 2·4 per cent. ; white cells 10,375 per c.mm. (segmented neutrophil polymorphs 56 per cent., non-segmented neutrophil polymorphs 0·5 per cent., lymphocytes 36 per cent., eosinophils 3·3 per cent., basophils 0·5 per cent., myelocytes 3·5 per cent.). She was ultimately discharged as incurable after consultation with many specialists, the diagnosis being sarcoma with multiple metastases in the lungs. A further opinion was then sought from Mr. A. M. Hendry, who submitted the case to me for radiological examination and opinion. Radiographs (see Fig. 483 A) were taken on November 10th, 1944, on which I reported as follows :—

"Marked changes in the upper half of the humeral shaft (diaphysis only), which has fractured. The disintegration of the bone and the periosteal reaction are indistinguishable from



FIG 480B. Lipoid granulomatosis (6/11/46) after X-radiation.



FIG 481 Lipoid granulomata. The destructive changes in the femoral neck on both sides were so extensive that spontaneous fractures appeared to be inevitable Consolidation followed X radiation therapy

A. J. Ackermann has published an account with illustrations of a patient, a white male aged 25 years who complained of polyuria, polydypsia, pain in the chest back and both legs. Radiographs of the chest show a coarse reticulation and fibrosis with some bullæ appearances which might be due to an unresolved broncho-pneumonia or reaction to some inhaled irritant. The condition was originally diagnosed and treated as tuberculosis but no bacilli were found in the sputum. Radiographs of the skeleton showed multiple large cyst-like areas of destruction in the pelvis and the upper third of both femora, with isolated lesions in the spine. No lesions were recorded in the skull. He recorded the case as one of Tuberose Sclerosis, apparently because of the appearances of the lungs and the absence of cranial defects but the clinical and radiographic features suggest to the author that they are more in accord with a lipoid granulomatosis. The lesions in the skeleton bear a close resemblance in form and distribution to the case of the author's on pp. 634–7. The lesions shown in the lung in the other case of the author's on p. 638 might well have passed into the condition shown in *Ackermann's* case.

Swanson and *Teplick* record as an unusual case of Ewing's Sarcoma a white female aged 2 years who was normal during the first year of life. Then she began to cry on movement of the right shoulder. The upper arm became swollen. One month after the condition was diagnosed as acute osteomyelitis. It was explored but recovery was slow and incomplete. There were bouts of fever. Two months after radiographs of the skeleton were reported as normal but after another two months generalised changes were present. One month later the radiographs showed patchy decalcification of the whole skeleton with areas of destruction and calcification of vessels. The child died 6 months after onset. There was no autopsy. The radiographic appearances of this case suggest that it might have been a reticulo-endotheliosis rather than sarcoma.

Under the term **Platyspondylia Generalisata Myelomatosa** *Gösta Jansson* recorded a case which he regards as one of myeloma in childhood. The child was 9 years of age and sickened with recurrent fever and pains in the back followed by progressive anæmia which brought him to hospital on December 12th, 1942, emaciated, cachetic, very pale and complaining of attacks of pain in the back and legs which were brought on by even slight movement. There was no albumen in the urine. Erythrocytes were reduced to under 1 000 000. Radiographs showed multiple rounded areas of bone destruction which in the ilium and upper third of the femora were almost confluent. Much osteoporosis on both sides of the metaphyses of the femora, tibiæ and fibulæ; less marked changes in the humeri. The spine showed platyspondylia. No changes in the skull. Urine not examined for Bence Jones proteose and sternal puncture was not successful. The patient died of pneumonia on February 14th, 1943, *i.e.*, 2 months from admission. At post mortem a myelomatous infiltration with varying type of cells of most of the viscera was found. He states that examination by sternal puncture gives no information as to the type of cell which predominates the myelomatosis. He cites *Naegeli*, who states that it may be myelocytic, myeloblastic lymphocytic, plasmacellic, erythroblastic or mixed-celled myeloma. The platyspondylia was generalised as in osteogenesis imperfecta, not as in lipoid granulomatosis. In the cases cited Bence-Jones body was not found. The duration was short and ended fatally. The skull was not involved in this case.

Niemann-Pick's Disease is found most commonly in Jewish infants—possibly congenital—having a mongoloid appearance. The liver spleen and lymph glands may be very large. The skin is of a yellowish brown. Œdema and sometimes ascites is present. There may be emaciation through difficulty in feeding. Growth may be retarded. There is cherry-red spot in macula and secondary anæmia, vacuolated cells in blood. Mental and physical degeneration leads to an early death. The normal parenchyma cells are

osteomyelitis but there are multiple rounded secondary lesions in the lungs These certainly suggest the diagnosis of sarcoma. In view of the hopelessness of any operative procedure is there any use in administering sulphathiazole or its fellows in the hope that they are inflammatory secondaries ?

Mr Hendry consented to my suggestion. He put the fractured arm in a short plaster and advised the administration of sulphathiazole (0 25 g) every 4 hours for five weeks

Subsequent clinical and radiographic examinations on November 30th 1944 and January 4th 1945 showed a progressive worsening of the signs The radiogram of January 4th (Fig 483 B) showed further disintegration of the upper half of the humerus and progressive development of the multiple rounded lesions scattered throughout the lungs. These appearances and her grave clinical condition suggested that the lesions had not responded to sulphathiazole

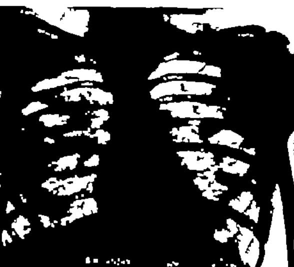


Fig. 483B Further disintegration of humerus with fracture and increase in number and size of multiple lesion in lungs (4/1/45).

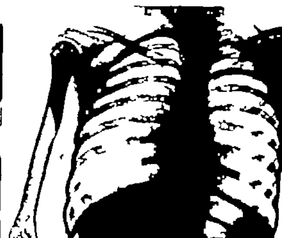


Fig 483C. Reconstitution of humerus and disappearance of lung lesions (12/9/45).

and now appeared to be hopeless. During the following month her retrogression continued. She was taken to three *other consultants independently* and *all* confirmed the *hopelessness of* general sarcomatosis At the end of February she began to show signs of improvement and at the beginning of May Mr Hendry received a report that the patient had recovered and was running about again like a healthy child. A further radiographic examination made on May 10th showed that the bone lesion had resolved and the multiple lung lesions had disappeared. *This excellent result has been maintained since The humerus is now (1946)* indistinguishable from the normal (Fig 483, C)

Comments Prior to treatment the clinical signs and the radiographic appearances of this case were, on the whole, in support of bone sarcoma with multiple metastases in the *lungs, but, as indicated, the bone lesion radiographically suggested an inflammatory* focus.

The absolute cure is phenomenal and quite distinctive from the results of any treatment in sarcoma or osteomyelitis. The only treatment was a course of sulphathiazole, but even when this was concluded the lesions seemed to progress for about a month and the clinical condition appeared hopeless to several consulting physicians and surgeons. The possibility that the condition was xanthomatous must not be overlooked for silent bone destruction and complete reconstruction can occur in this disease : multiple lesions may develop in the lungs, see *Ackermann* case (p 630) also *Posner* p. 635

It may be thought regrettable that no biopsy was performed, but experience suggests that the evidence thus obtained might have been dangerously misleading It would have made no contribution to the cure it might have retarded it.

formed, or the old ones become enlarged is undetermined but by injecting the surface of the part it appears eventually much more vascular than the other parts The surrounding parts are also inflamed, as the periosteum and the cellular membrane and often take on an ossific inflammation This produces another process first absorption of the earthy matter and all the surface between the living and dead parts of the bone becomes as soft as if steeped in acid while the dead part remains as hard as ever To complete the separation, the absorbents continue their office and absorb the living parts also." These findings of *Hunter* are largely confirmed by my radiographic investigations.

Had his teaching been fully appreciated, recent faulty interpretations would have been avoided and patients have been spared some of the disasters attendant upon necrotic bone. These changes have been recorded in most of the secondary and some of the primary centres of ossification.

A brief summary of the sites at which these changes have been noted and the names of the first observer is as follows —

Tubercle of tibia (*Osgood* 1903 *Schlätter* 1903); Tarsal scaphoid and patella (*Köhler* 1908) Epiphysis of head of femur (*Calvé*, *Legg* *Waldenström* and *Perthes* 1910); Os calcis (*Haglund*, 1907) Head of second metatarsal (*Freiberg* 1914) Vertebral epiphyses (*Scheuermann* 1921) Sternal end of clavicle (*Freidrich*, 1924) Head of humerus (*Lewin*[1] 1927) Internal epicondyle of humerus (*Legg* *Lóhr*[1] 1930); Olecranon, great and lesser trochanters (*Monde Felix*, 1922); Heads of metacarpal bones (*Mauclaire* 1927) Iliac crests (*Buchman*,[2] 1925); Pubis (*Van Neck*, 1924) Patella (*Sinding Larsen*); Upper end of tibia (*Ritter*[1] 1929) Lower ends of tibia and fibula (*Stern*) Astragalus (*Diaz*,[1] 1928) Epiphysis of first metatarsal (*Wagner* 1930); Bipartite patella (*Meisels*[2] 1928); Carpal scaphoid (*Preiser*) Medial sesamoid of first metatarsal (*Renander*[1] 1924)

Other sites, including the superior lip of the acetabulum, the vertebral body the femoral neck, the neural arch of the fifth lumbar the accessory tarsal scaphoid, the adult scaphoid, the acromion, sesamoids of great toe the pisiform, have all been seen in the author's series. The common and best known lesion of this description is that condition of the tarsal scaphoid described by *Köhler* and that associated with the names of *Calvé* *Legg* *Waldenström* and *Perthes*, who, in 1910 independently described these changes in the epiphysis of the head of the femur

Many explanations have been put forward to account for these changes. They include trauma, sepsis, tuberculosis, embolism of the nutrient artery disturbances of the sympathetic innervation, and endocrine dyscrasia.

The clinical signs and radiographic appearances seen in osteochondritis of the upper femoral epiphysis may be taken as a fair average of the signs and appearance of this condition in other bones.

Briefly they consist of —

(1) Pain with negative radiographic appearances

(2) Absence of symptoms but the development of marked radiographic bone changes.

(3) Reappearance of symptoms—radiographic evidence of deformity of the involved bone

(4) Symptoms of chronic arthritis and radiographic evidence of these changes in the deformed joint.

In the first stage the patient complains of pain, but the radiograph may show no bone abnormality Attention at this stage should be concentrated on the relative density of the suspected bone as this is the first radiographic sign and one which is readily

replaced by vacuolated cells There is a disappearance of the normal fat but overloading of blood and tissues with phosphatide No definite bone changes have been recorded.

Gaucher's Disease occurs in early childhood an acute form has been described in infants. Child has pain along the bones and a yellowish brown skin. A large spleen associated with anæmia is present and later the liver enlarges The anæmia and leucopenia are progressive ecchymoses and tarry stools Yellow wedge-shaped thickening of ocular conjunctivæ. Gaucher's cells not found in blood. The thrombopenia which develops returns to normal after splenectomy Radiography of the bones shows osteoporosis with collapse of one or more vertebral bodies with later some cyst like areas of destruction, thinning of the cortex of the long bones flask like expansion of the lower third of the femora. Gaucher's cells in the lymph glands containing kerasin. Most of the reticulo-endothelial tissue and central nervous system involved

Flecker has illustrated the radiographic appearance of wine-bottle expansion with osteoporosis of the lower third of the femur He regards this as the characteristic appearance in Gaucher's disease. The author has found a similar appearance in some cases of hyperthyroidism and leukæmia.

Steiner confirms Gaucher's finding, and in addition records cortical thinning of the long bones, and also lumbar kyphosis associated with collapse of the vertebral bodies. No changes are recorded in the skull.

The radiographs of the bones of a case of Gaucher's disease described by *Junghagen* [2] show osteoporosis, coarsened cancellous trabeculation and areas of cancellous destruction. The radiographs of the spine show collapse of some of the vertebral bodies, and biconcave deformity of the others, with biconvex expansion of the discs, as in osteomalacia.

Interesting cases have been recorded by *Burton* and *Worth*

Papers published by *Schüller* [1] *Christian, Rowland Sosman* [2] *Cignolini, Lyon* [1] and *Merum Weiss,* [1 and 2] *Rothnem Frimann Dahl* and *Forsberg* and *Lazareva* give further details and illustrations of cases of lipoid granulomatosis

Xanthomata of tendons synovia, etc., are not associated with xanthomatosis (see p 706)

OSTEOCHONDRITIS AND AVASCULAR NECROSIS

The author uses the term osteochondritis to indicate those reactions associated with hyperæmia and decalcification which are produced in the living bone by adjacent avascular bone or cartilage The dead or avascular fragment as long as it remains such, cannot exhibit these reactions but it appears to attract calcium (probably by a chemical affinity) removed during the active hyperæmia from the adjacent living bone *Consequently the dead bony fragment becomes increasingly dense as the living bone* loses its calcium, becomes plastic, and capable of deformity by pressure. Later as vessels grow into the dead fragment, its integrity and homogeneity is destroyed, it collapses and appears to fragment. The hyperæmic reaction, and all that it entails *from plasticity* does not cease until all dead bone has been removed. The time taken for this varies in the case of the large avascular fragment such as the femoral head, it may take upwards of three to four years.

Before X-rays were discovered, *John Hunter* had given us the true explanation of the changes In one of his lectures he states "When a piece of bone becomes absolutely dead, it is then to the animal machine as any other extraneous body and adheres only by the attraction of cohesion to the machine The first business of the machine therefore is to get rid of this cohesion and discharge it For affecting this separation there are several natural and successive operations going on. The first effect of the stimulus is on the surface of the living bone which becomes inflamed whether new vessels are

case is the absence of change in the articular surface and a return to normal function Quoting from *Waldenström's* article in 1938 "It should be remembered that most cases heal with a deformity which is only slightly troublesome, at least up to 50 years of age," and repeating Gill's statement "the end results are practically perfect hips."

Congenital Dislocation of Femoral Head and Legg's Disease. The changes in the femoral head and neck which have been forcibly twisted and turned during attempts to reduce a congenital dislocation are not radiographically identical with those seen in Legg's disease. The serial radiographic appearances of fragmentation following surgical trauma to the dislocated femoral head are not identical with those in Legg's disease, except as in the cases to be cited later In Legg's disease the appearance of fragmentation is seen in the destructive phase, whereas in the case of surgical trauma it appears to occur in the regenerative phase. In the latter condition, the fragmentation resembles the ossification of the femoral head in hypothyroidism, but the epiphyses will not stand up to normal weight bearing and so are deformed as are the epiphyses in Legg's disease, but in Legg's disease the deformity occurs during disintegration rather than during reorganisation. The changes following surgical trauma take place more rapidly than do those in Legg's disease and are sometimes associated with serious damage to the growth cartilage, resulting in marked stunting of growth—a feature absent from Legg's disease. In some cases trauma may for some years appear to have destroyed the process of ossification within the cartilage of the epiphysis. The author believes that the changes which follow forcible reduction of the femoral head in healthy children are due solely to the trauma involved the additional debilitating factor present in Legg's disease is usually absent, hence the readier healing However the author has seen typical Legg's disease develop in the opposite normal hip during recumbent treatment of the dislocated hip, which did not undergo any such change.

Dissolution of Epiphyseal Union. It is very rare for the femoral diaphysis to be displaced from the capital epiphysis during forcible manipulation (the author has seen it in 2 cases only these were young patients in whom the metaphyses exhibited the signs of rickets), for in this case also some additional debilitating factor is necessary to weaken the bond at the growth cartilage. When, however such a weakened bond is broken by trauma and the epiphysis is so much displaced that its blood supply is cut off, the changes which it undergoes are not those seen either in the simple trauma described or in Legg's disease. The author has witnessed and recorded the typical serial time-table of osteochondritis initiated in the bone forming the roof of the acetabulum in a case of slipped epiphysis, where fusion of the epiphysis and diaphysis occurred in the displaced position without any sign of avascular necrosis of the femoral head or damage to the articular cartilage.

Healing of the slipped epiphysis is associated with fusion of the epiphysis and diaphysis. This is not observed in Legg's disease, but it sometimes occurs as the result of trauma entailed in reducing congenital dislocation in which secondary changes in the injured epiphysis somewhat resemble those in Legg's disease The mass necrosis of the femoral head and the marked pressure deformities of the plastic bone of the neck, which occur in some cases after dissolution of the bond between the diaphysis and the epiphysis, create quite a different picture, in which the articular cartilage is often involved.

In 1933 the author described a preslipping stage of slipped epiphysis; denoted by the radiographic evidence of pathological changes in the growth cartilage which united the diaphysis with the epiphysis. Briefly this consists of reaction in the bone bordering both sides of the growth cartilage, resulting in an apparent excavation of the bony epiphyseal border and erosion of the diaphyseal surface. The outline of the unaffected

missed. The contour and structure of the bone is regular It shows no evidence of osteoporosis. This apparent increase in density is due to interference with its blood supply The appearance may be intensified by a concomitant slight decrease in the calcium content of the neighbouring bones due to their enforced functional rest occasioned by the lesion, for a similar appearance is seen in radiographs of the wrist soon after reduction of a dislocated semilunar bone. The dislocation must have interfered with the blood supply of the dislocated semilunar and it retains its density while the other bones of the wrist show a decrease in density as a result of the enforced disuse.

Later the dead bone appears to attract calcium for it increases in density as the living adjacent bone is decalcified.

In the second stage the patient may be relatively free from symptoms and the fears which were entertained of a tuberculous hip are dispelled.

If further radiographic evidence is sought to support this clinical cure" an astonishing change may now be seen in the epiphysis. Instead of the normal shape and uniform density the outline shows pressure deformity and islands of dense bone in a relatively radiotranslucent matrix may be seen. The explanation for these changes is the avascular bone is gradually invaded by vessels bringing decalcification and splitting up of the "sequestrum. The fragmented bone has not the stability of the entire bone Radiographs at three monthly intervals will show the progress of the lesion. If the part is not put at rest from weight or stress in this stage, marked pressure deformity will occur

When the lesion is fully established, pain or discomfort may again become prominent, and in the case of superficial bones marked swelling of the overlying soft tissues is present.

Eventually the affected bone shows evidence of consolidation. The condensed islands lose their density and merge with the recalcified bone. The clinical signs and symptoms will now be dependent upon the degree of deformity but, as a rule, at this stage they are slight. They only begin to attract attention years after when the faulty articular surfaces begin to show the changes of chronic arthritis. Examples of these lesions are illustrated and described in the chapters dealing with anatomical distribution.

More recently it has been stated that Legg s Disease is not an osteochondritis but simply an avascular necrosis; also that osteochondritis and avascular necrosis are one and the same condition and are indistinguishable. *Axhausen*, in 1928, suggested that avascular necrosis produced by mycotic emboli was one of the features in osteochondritis.

The latter term embraces also the more important concomitant living process, producing decalcification and a plasticity in the neighbouring bone, which permits of deformity when pressure is applied. In some of these cases it is osteoporosis which dominates the picture, and there is no sign of a necrotic fragment. It was pointed out by *Phemister* in 1930 that "Histologically the majority of these lesions appear to have something more back of them than a simple bland embolus or injury cutting off the circulation and producing aseptic necrosis.

The radiographic appearances of the successful autogenous bone graft do not suggest that it behaves as a necrotic fragment, as has been suggested. The relative rapidity (often within from 3 to 6 months) with which the graft is incorporated into the bone that it bridges suggests that it retains life throughout. These radiographic appearances do not include the hypercalcification and fragmentation such as are seen in osteochondritis. It has been stated by Watson Jones that "if the avascular fragment carries with it the articular cartilage of a joint, the outlook is wholly changed. Replacement of the hyaline cartilage with fibrous tissue or with an imperfect fibro-cartilage is almost *inevitable, and survival of the joint is relatively rare." This is certainly not the clinical or* the radiographic finding in Legg s disease *the characteristic feature of the carefully treated*

density does not indicate that the fragment is necrotic for it is seen in fractures, a the successful autogenous bone graft, which, for a time after its insertion, retai density although the fragments which it bridges undergo decalcification. Whe graft has taken, it too loses calcium and becomes of the density of the recipient With increased function the mended bone wholly increases in density There suggestion of fragmentation or of hypercalcification it appears that living cells persisted throughout the whole graft, being sustained by the plasma which has b them, until revascularisation has been established. We cannot say that because a ment of bone exhibits this temporary retention of calcium it is necrotic.

If a bone fragment is necrotic it is friable and, like other dead tissue, may and does attract calcium from the plasma and causes a drain on the calcium of ad bone. Therefore, the necrotic fragment acquires an added density which can be r nised by comparison with normal bone in the opposite limb. As long as this h calcification persists, the part exhibiting it must be regarded as necrotic. In tumours which have caused necrosis of a fragment, the hypercalcification persis the remainder of the patient's life but, if the necrosis is due to vascular distur brought about by trauma, the fragments are gradually infiltrated with living cell the bone takes on abnormal plasticity the infiltration showing as ill-defined zo decalcification, often more marked at the periphery Some authorities deny hypercalcification occurs. It has been seen by the author in epiphyses, sesamoid in localised bones such as metacarpals and phalanges. Associated with Paget's di it was present in isolated small bones for more than 5 years without producing any loc symptoms or clinical sign.

The basal epiphysis of one or more of the terminal phalanges of the hand sometimes exhibit an abnormal density which has led to the diagnosis of ava necrosis of the epiphysis. This is an error It is a variation in the ossification terminal phalanges—a variation which is not associated with any pathological ch (see Fig 52). Therefore not all bone exhibiting hypercalcification is necrotic addition, there must be sequestration of the fragment, which retains its sharp o or evidence of friability and later so-called creeping substitution, in which the c fragments are apparently undergoing dissolution and becoming plastic. This p menon, which the author calls the oscillating interchange of calcium between the ne and the adjacent living bone, can be best seen in *Köhler's* disease of the tarsal navi The blood supply to the navicular is apparently cut off the bone gradually at calcium from the neighbouring tarsal bones, so that they show progressive decalcifi as the navicular increases in density The dense bone is compressed and later may the appearance of fragmentation with gradual dissolution of the fragments. The is regenerated from the periphery and, as the dense islands disappear the other bones increase in density the last area to acquire normal density often being the site last dense island (see Figs. 182, A, B C and D). If the avascular necrotic bone is in p of substitution, the trauma of normal function may cause a localised check to the pro re-ossification of the affected area may fail, or the sequence of changes of osteochon may reappear within it. The new bone which has been substituted for the ne fragment and adjacent plastic bone is sometimes of a very coarse cancellous struc

The question may be asked when and for how long can one recognise this incr density? The answer is As long as the fragment is avascular and necrotic it will its density it will gradually lose it as it becomes infiltrated with living cells. It a fleeting process, for in the case of the necrotic femoral head in any of the cond which have been considered, the radiographs will afford evidence of contrasted d from the first or second month until the third or fourth year In the case of the

epiphyseal border is rendered clearer but, in contrast the diaphyseal surface becomes ill-defined and woolly while the metaphysis itself appears to be thickened. If this evidence is heeded and the joint is protected the slipping and the possibility of subsequent destructive changes might be prevented Recently it has been asserted that no such preslipping stage exists, and that the failure to detect slipping is due to the fact that no lateral radiographs have been taken. The writer agrees that in some cases slipping may escape the novice s attention in the antero-posterior radiographs as readily as in the lateral view

The clinical history of the typical case supports the author s radiographic findings. Symptoms are often present for months before the actual dissolution takes place, usually without any history of trauma, and radiographs at this stage will not show displacement. The latter often occurs without warning and the symptoms become suddenly more prominent, frequently as a result of trauma which would not have damaged a normal joint. Antero-posterior and lateral radiographs will then show the displacement, one projection sometimes demonstrating it better than the other In the cases of slipped *epiphysis which the writer has previously reported in the preslipping stage no sign of* slipping was shown in the antero-posterior or lateral radiographs. An experience which has been more recently confirmed by *M Beckett Howorth*

The femoral capital epiphysis may be detached and rendered avascular by forcible abduction during the treatment of rachitic coxa vara (see Figs. 251 A and B).

Fractures of Femoral Neck. Fractures of the neck of the femur in children are much more rare than either Legg's disease or dissolution of the epiphyseal union. The author has seen only 15 such fractures during the past 20 years. The majority of these were in the base of the neck more than half of them showed vascular changes, a finding which is supported by *Brandon Carrell* and *W B Carrell* and by others. The radiographs of such lesions shortly after the accident do not show any difference in the density of the fragments, but, after about 1 month a zone of increased density having an ill-defined border may be seen against the fractured surface on the proximal fragment denoting interference with vascularity

During the next month, and for a varying number of months afterwards, the whole of the proximal fragment retains its density while in the trochanteric area and in the shaft diminished density gives evidence of decalcification. The neck of the proximal fragment may show an added density with blurring of the outline of the fractured end of its cancellous structure. Unless the fragments are sufficiently immobilised at this time, coxa vara deformity will develop, as the bone is plastic. Union of the fragments may be noted at the end of about 3 months, after which the density of the neck fragment gradually disappears. For some months the femoral head may show uneven density the subarticular bone may appear to be almost completely decalcified. Pressure during this time appears to result in damage to the articular cartilage with subsequent arthritic changes. If the head and neck fragments retain their density and the fractured surface its sharpness of contour avascular necrosis is established and several years may elapse before restoration is complete.

Fractures of the femoral neck in adults are frequently associated with localised necrosis of the head fragment, particularly if this has not been immobilised

From this it would seem that the contribution required from radiography is recognition of avascular necrosis since it cannot be recognised in any other way

Radiographic Evidence of Avascular Necrosis. If a fragment of bone is deprived of its blood supply after a latent period of 3–4 weeks, it will not exhibit the decalcification of the adjacent bone which results from the disuse occasioned by the injury : consequently in the radiograph it will appear denser than the living bone This relative

Study of the radiographic appearances in these cases of pinning of the femoral neck provides evidence that irrevocable damage may be done to the femoral head by weight bearing before the fragments have consolidated or reorganised. Since it is impossible to tell by radiography or in any other way if and to what extent, the vascularity of a fragment has been disturbed after pinning the patient should be kept in bed for from 2 to 3 months. At the end of that time radiographs will indicate whether there is any disturbance of vascularity and if union is taking place If the head fragment at that time has the density and appearance of necrosis, one can reckon that it will be 3 or 4 years before substitution of the necrotic fragment is complete. Until radiographs show that this has occurred, even though they reveal union of the fragments, weight bearing will result in displacement, deformity and prolonged disability Immediate operative measures for removal of the necrotic fragment and ankylosis of the joint would result in a shortened period of invalidism, a factor of greater importance in adults.

The author's views [57] on Avascular Necrosis and Osteochondritis are summarised as follows:

(1) Disturbance of the vascularity of bone by trauma, emboli, inflammatory or neoplastic changes may result in avascular necrosis of the affected bone.

(2) Avascular necrosis becomes associated with osteoporosis of the adjacent bone and the phenomenon known as osteochondritis, although it is not always a recognisable factor in the latter condition.

(3) Radiographs may show evidence of disturbance of the vascularity of a fragment of bone within 6 weeks of the application of the causal factor If the signs of osteochondritis develop in association with avascular necrosis, the necrotic fragment will be recognisable by its relative density throughout the whole period of reorganisation, *i.e.*, for upwards of 4 years.

(4) It is the long period of bone plasticity in osteochondritis (1 to 4 years) to which the clinician should give due attention, for disregard of this is responsible for the deformities caused by stresses and strains on the inadequately immobilised joint surfaces. Avascular necrotic bone undergoing substitution displays a plasticity which persists over a similar period.

(5) Osteochondritis presents a characteristic radiographic time table (see p. 283) If the affected part is spared from stresses and strains during plasticity regeneration is perfect.

(6) The radiographic changes of Legg's disease and those following surgical trauma in reducing congenital dislocation of the femoral head, traumatic dislocation of the femoral head, fractures of the femoral neck, and displacement of the femoral diaphysis from its capital epiphysis are not identical: they vary from complete restoration to complete destruction of the joint, although avascular necrosis may occur in many of these conditions.

(7) Radiographs do show evidence of pathological changes in the metaphysis of the upper femur in some cases before disintegration and displacement produce the lesion known as slipped epiphysis Due attention to this radiographic finding and the prompt institution of protective measures may prevent the displacement and the consequences of avascular necrosis of the epiphysis

(8) Osteochondritis dissecans produces symptoms when the fragment becomes necrotic or displaced the lesion may be recognised radiographically several years before

(9) Temporary retention of calcium by a fragment of bone does not indicate that the fragment is necrotic it may fuse without any of the secondary changes characteristic of necrotic bone

(10) Avascular necrosis of bone can be detected radiographically by the greater

tarsal navicular in which the regeneration is quicker the hyper-calcification is recognisable for about 1 year In the proximal necrotic fragment of the carpal navicular it may be detected continuously for from 18 to 24 months. Although it has been stated by one author that "in Legg's disease, if the hip is immobilised so that disuse calcification arises and many radiographs are taken at weekly or fortnightly intervals, one film will show failure of decalcification of the epiphysis. This stage is transient and may easily be overlooked the radiographic indication is that it is not even necessary to immobilise the hip-joint in Legg's disease to secure contrast in the compressed or fragmented epiphysis it is often found in the first radiograph of the active child, and, as has been indicated, persists for upwards of 4 years.

Pinning of the Femoral Neck. As in the first month radiography affords little or no evidence of avascular necrosis, and since during this period it is usual for the pin to be inserted, the surgeon can have no knowledge whether or not aseptic necrosis exists when he operates. Further because it is pinned and function is permitted soon after the living bone will not lose its calcium, and the contrast density of the fragment which has had its circulation disturbed will not be revealed by the radiographs The first and only indication of this condition after several months may be fracture and compression of the superior surface of the femoral head. The pain and discomfort associated with this, leading to removal of the pin and a period of freedom from weight bearing, brings about some decalcification of the living bone, and the contrasted density of the necrotic fragment may then become apparent in the radiograph and persist until the fragment has been absorbed or removed. During revascularisation of the fragment, it and the adjacent bone become plastic and may be deformed by pressure the pin may cut through the femoral head and neck and even the bony wall of the pelvis, as through cheese. Destructive changes in the articular cartilage of the compressed femoral head, disintegration of the bone, and deformity of the joint surfaces ultimately develop. Intrusion of the pin into the joint surface results in erosion of the articular surface. Absorption may be seen along the track of the pin, which is loosened. The pin may be extruded, and, because the fractured surface is no longer protected, displacement may occur

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Actually in ununited fractures of the femoral neck not treated by pinning or other internal splinting the articular surface of the separated head appears to be preserved intact for many years, even the pre-existing signs of osteo-arthritis may disappear from the radiograph, an example of the value of rest in treatment.

Study of the radiographic appearances in these cases of pinning of the femoral neck provides evidence that irrevocable damage may be done to the femoral head by weight bearing before the fragments have consolidated or reorganised. Since it is impossible to tell by radiography or in any other way if and to what extent, the vascularity of a fragment has been disturbed after pinning the patient should be kept in bed for from 2 to 3 months. At the end of that time radiographs will indicate whether there is any disturbance of vascularity and if union is taking place. If the head fragment at that time has the density and appearance of necrosis, one can reckon that it will be 3 or 4 years before substitution of the necrotic fragment is complete. Until radiographs show that this has occurred, even though they reveal union of the fragments, weight bearing will result in displacement, deformity and prolonged disability Immediate operative measures for removal of the necrotic fragment and ankylosis of the joint would result in a shortened period of invalidism, a factor of greater importance in adults.

The author's views [37] on Avascular Necrosis and Osteochondritis are summarised as follows

(1) Disturbance of the vascularity of bone by trauma, emboli, inflammatory or neoplastic changes may result in avascular necrosis of the affected bone.

(2) Avascular necrosis becomes associated with osteoporosis of the adjacent bone and the phenomenon known as osteochondritis, although it is not always a recognisable factor in the latter condition.

(3) Radiographs may show evidence of disturbance of the vascularity of a fragment of bone within 6 weeks of the application of the causal factor If the signs of osteochondritis develop in association with avascular necrosis, the necrotic fragment will be recognisable by its relative density throughout the whole period of reorganisation, *i.e.*, for upwards of 4 years.

(4) It is the long period of bone plasticity in osteochondritis (1 to 4 years) to which the clinician should give due attention, for disregard of this is responsible for the deformities caused by stresses and strains on the inadequately immobilised joint surfaces. Avascular necrotic bone undergoing substitution displays a plasticity which persists over a similar period.

(5) Osteochondritis presents a characteristic radiographic time table (see p. 283) If the affected part is spared from stresses and strains during plasticity regeneration is perfect.

(6) The radiographic changes of Legg's disease and those following surgical trauma in reducing congenital dislocation of the femoral head, traumatic dislocation of the femoral head, fractures of the femoral neck and displacement of the femoral diaphysis from its capital epiphysis are not identical they vary from complete restoration to complete destruction of the joint, although avascular necrosis may occur in many of these conditions.

(7) Radiographs do show evidence of pathological changes in the metaphysis of the upper femur in some cases before disintegration and displacement produce the lesion known as slipped epiphysis Due attention to this radiographic finding and the prompt institution of protective measures may prevent the displacement and the consequences of avascular necrosis of the epiphysis.

(8) Osteochondritis dissecans produces symptoms when the fragment becomes necrotic or displaced the lesion may be recognised radiographically several years before.

(9) Temporary retention of calcium by a fragment of bone does not indicate that the fragment is necrotic it may fuse without any of the secondary changes characteristic of necrotic bone

(10) Avascular necrosis of bone can be detected radiographically by the greater

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examples of avascular necrosis can be seen than in those cases of fractures of the long bones which were treated by intramedullary pegging much of the graft can be recognised 10–12 years after it was inserted while the adjacent bone shows the concomitant osteoporosis which accompanies necrotic bone

Aseptic Necrosis in Other Sites. Radiographs illustrating these conditions are shown in Figs. 70, 96 E, 123 (Semilunar), Fig 96, E (Elbow) Fig 123 (Accessory scaphoid and sesamoid), Figs 180, 182, 183–185 (Second metatarsal head), Fig 182 (Tarsal scaphoid) Figs. 183–135 (Adult tarsal scaphoid) Fig 198 (Knee), Figs. 248, A and B (Acetabulum) Fig 256 (Femoral neck) Figs 253 265–271 (Femoral head) Figs. 364 365 384 (Spine)

Radiation Aseptic Necrosis of Bone. As the result of prolonged or intensive radiation, possibly due to damage to the vascular supply to the periosteum and the finer intimate cellular contents of the bone, bone appears to become devitalised and lose its delicate structure and elasticity Radiographs will show destruction of the exquisite bony architecture the trabeculæ may assume a granular appearance with areas more or less circumscribed from which the trabeculæ appear to have been absorbed. Such bones subjected to stresses or strains will fracture more readily than normal The radiographic appearances may be erroneously regarded as indicating invasion of the bone by malignant cells—particularly as the necrosis occurs in the area of a lesion irradiated because of malignant changes. Accounts of patients exhibiting these changes have been recorded by *J Ewing*[1] *H Strauss* and *McGoldrick* *M B Stewart*, *J D Camp* and *D Moreton* and others.

K Kulsen-Hansen has published an account of 4 cases of fracture of the femoral neck following X radiation therapy The patients had received from 2,800 × 4 to 3,000 × 4 roentgen dose and the fractures occurred from 6 to 18 months after pain was experienced by 2 of them some months before the fracture occurred

Gratzek, *Holmstrom* and *Rigler* have also given an account of avascular necrosis and other changes following X radiation.

Incomplete Fractures. These are definite fractures of bones which, as they are not associated with the slightest displacement of the fragments may not be associated with signs or symptoms of sufficient severity to call for radiography in the first instance or even when such reference is made may not be revealed by the ordinary antero-posterior and lateral radiographs Such fractures occur perhaps more frequently in the scaphoid, the second metatarsals the upper and less frequently the lower third of the tibial shaft, os pubis, the neck of the femur and the lower end of the radius, the first rib but examples have been seen in many of the other bones. In some cases additional radiographs with oblique or tangential projections may reveal with the help of a lens, the line of fracture; in others no matter how careful the radiography and its inspection, no evidence of fracture can be detected In some cases the injury was sustained at a time when the patient's mind was actively excited or employed in pleasure, passion or even contemplation and the injury passed unnoticed because of the more attractive incidents proceeding at the time. Thus, in the notes of a soldier who had been picked up from the beaches at Dunkirk and was later discovered to have extensive myositis ossificans of both thighs, it was stated that there was no history of any trauma. Because of this the patient does not seek advice perhaps for 3 or more weeks, when his or her attention is attracted to the site because of localised pain or by a blow perhaps relatively trifling which was accompanied by an undue amount of pain. On examination the skin may be a little reddened and heated and a suggestion of some bony thickening may be detected which is tender on pressure. At this stage radiographs may reveal on one projection, in the case of the long bones, a slight periosteal bump at the site of the fracture with some ill-defined increase in density around the line taken by the

density of a fragment which may exhibit friability associated with decalcification of adjacent bone and by the *serial radiographic changes which show gradual absorption* of the dense and apparently structureless fragment Hypercalcification of bone is not in itself an indication of avascular necrosis.

(11) As long as the necrotic bone is present, decalcification and plasticity of adjacent bone will exist hence, the indication is that necrotic bone in traumatic cases should be removed as soon as detected, if for any reason the part cannot be efficiently immobilised until complete restoration can be detected radiographically

(12) The destructive changes in the hip joint, due to avascular necrosis following internal splintage (pinning, etc.) are worse than after any form of external immobilisation. The pin gives a false sense of security which lessens the period of freedom from weight bearing the latter and possibly added vascular damage by the pin, probably account for these disasters.

(13) No sign of avascular necrosis can be detected during the first month after the trauma this latent period will be extended to many months if the femoral neck is pinned and the limb is allowed to bear weight.

(14) The recognition of avascular necrosis and, thereby prevention of its important complications would be facilitated if after pinning the patient rested in bed with the limb immobilised for 3 months.

(15) The clinical signs and symptoms of disease usually disappear (at any rate for a time) long before the plasticity of the bone. Treatment must therefore be regulated by the radiographic appearances and not by the absence of clinical signs or symptoms. The plasticity of the bone can be judged by the radiographic appearances only ; therefore, rest of the affected bone should be enforced as long as the radiographs suggest plasticity

Special mention should be made of Kienbock's disease for the sequence of changes seen in the lesion of the semilunar differ from those in Köhler s disease of the infant tarsal scaphoid and Calvé's vertebra plana. In the two latter the affected bone is compressed and hypercalcified but regenerated from the periphery and the excess of calcium removed In the case of the semilunar which occurs in adult life this type of regeneration does not take place—my opinion is that it may do if complete immobilisation were secured from the onset until regeneration had completed. I have not been able to get the prolonged immobilisation this demands. Untreated affected semilunar bones appear to retain their density and irregularity for years and eventually secondary arthritic changes are set up in neighbouring joints. The appearances suggest the sequestration phenomena which occur in the calcified gland, fibroid or other dead tissue. These hold their excess of calcium and are never resolved. This further suggests that instead of removal of the semilunar as the surgical treatment, a vascular supply might be carried into it by a graft from adjacent living bone which would lead to substitution of the necrotic bone Congenital fusion of the semilunar to adjacent bone occurs and permits of full function.

Aseptic Necrosis in Caisson Disease. A number of authors have recorded cases under this heading notably *Bornstein* and *Plate Bassoe Kahlstrom Burton* and *Phemister*

The condition is brought about by the slower liberation from the fat and marrow of gas which had been taken up while the individual was subjected to considerable gaseous pressure Radiographs show necrosis of localised areas of bone more frequently in the head and upper third of the femur humerus and tibia and in the lower half of the shaft of the femur and tibia. At post mortem these areas showed necrosis of the contained elements and reactive changes in the surrounding tissues. The lesions persist for years and may bring about destruction and collapse of the articular surfaces involved. Some of the areas show deposition of calcium and have radiographic appearances similar to the more familiar lesions in the lower third of the femoral shaft (see p 210). No better

803). *Brandt* contrasts these lesions with the exhaustive fractures which occur tals *Henschel*, by spectoradiographic examination of the fine structure of bone, to the opinion that a grouping of the crystalline elements across a zone subjected se strains occurs, and, unless this is allowed to recover by rest further trauma esult in slipping The appearances of *Looser's* "umbauzonen differ from the fracture in several respects Though no displacement occurs in the first ce the zone is broader than the acute traumatic fissure, its boundaries are d, rather than sharp and clearly defined, and they sometimes exhibit an increased) These lesions are not seen in normal bone they occur frequently in nalacia, renal rickets Type B The type of incomplete fracture seen in Paget's e, Hyperparathyroidism, Osteogenesis imperfecta, have rather different characters these, complete spontaneous fractures occur through pathological bone. In es of the central nervous system, such as Tabes dorsalis, spontaneous fractures through bone which has normal radiographic characters. Further details are in other chapters (see index)

ost-traumatic Osteoporosis. The bones of a limb which is immobilised following a or a localised surgical operation show a gradual and somewhat irregular decal ion even of those bones which were not involved by the injury As illustrated by thor [19] serial radiographs of the bones often show very marked changes, not only calcium content but in the cancellous and compact structure of the bone. The lous extremities of the long bones, particularly in the neighbourhood of the seal line, though the epiphysis may have been fused with the diaphysis for years, a marked decalcification and consequent radio-transparency With the same re as for a normal limb the radiograph will appear to be considerably over d. With the time reduced sufficiently to give a correct exposure for the decalcified the radiograph will show a compact cortex to the shaft which gives the false sion of increased density and calcium content.

n examination of the structure of the bone in a serial collection of radiographs immobilised limb will reveal not only irregularity in density of the compact tissue, ch there may be cortical islands which are very radio-transparent, but very marked es in the cancellous structure. Coarse and thickened trabeculæ enclosing larger s appear to replace the fine and exquisite reticulation of the normal cancellous . These appearances may persist for a year or more after immobilisation of the has terminated, but eventually the delicate architecture of the normal is restored is a class of case however in which these retrograde changes show a ssive development in association with certain well marked clinical signs and toms.

'ollowing trauma, particularly in the neighbourhood of the multi-articular joints wrist and foot, but also in the neighbourhood of the larger joints such as the knee houlder a sequence of symptoms develop in some patients which may give rise diagnosis of tumour or tuberculosis. The trauma may in itself not occasion any pain or disability even that which is present soon after the injury may gradually pear Following a period of quiescence in the affected part or in the extremity to the injury a painful and disabling condition may develop which is not relieved st, and often resists all electro-medical applications. The affected part appears l, its skin thin, and red or bluish, and often moist. Movement of the part is painful. radiographs taken during the development of the condition reveal a progressive ification of the cancellous tissue, at first as small circumscribed foci in the cancellous mities of long bones, or in the short tarsal or carpal bones. The compact tissue of aft may appear to contrast with the decalcified extremities, but ultimately this,

fracture. The amount of reaction is dependent on the individual—generally speaking it is greater in the young person—the amount of movement between the fragments and the frequency and degree of strain of such movements. If the interval since the trauma has been longer some absorption of the damaged cancellous tissue will have taken place around the fracture line the calcium liberated apparently being stored in the adjacent bone which shows some increase in density In the case of the scaphoid this results in a cyst-like area of destruction in the walls of which a fissure may or may not now be detected. The fracture line may now be completely or partly visible In any case the zone is one of disorganisation through which, as in the case of any incompletely consolidated fracture refracture may occur with relatively slight trauma. Because of the symptoms the radiographic appearances and the absence of a definite history of injury the diagnosis of localised osteomyelitis or even sarcoma may be made but if the lesion is treated as a fracture by immobilisation, which it should be, healing will proceed without any interruption. If the bone has been permitted to function for some time after the fracture was sustained, healing will be associated with much reaction in the bone bordering the fracture which will be denoted by its density Consolidation sufficient for function will generally be present after an interval of 3 months. If the bone is permitted to function before there is radiographic evidence of consolidation, as with the more obvious fractures refracture will occur through the new bone. This will result in further haemorrhage and more massive callus formation. In some cases biopsy has been performed during the phase of activity *i.e.*, that denoted by localised cancellous absorption the appearances at operation have been those of healing fractures and the histological structure has been interpreted as indicating inflammation, but no organisms have been recovered and the lesion has regularly progressed to complete healing such as we seldom see happen in infective lesions The more serious erroneous diagnosis of sarcoma has been made in some cases and amputation advised. The error has not always been established when amputation has been performed, but in those cases where other conditions have prevented amputation complete resolution has followed.

These incomplete fractures have been given the names of march, overstrain, over load, wear and tear exhaustion, fatigue, and pseudo-fractures. Some authorities are of the opinion that they develop insidiously as the result of rhythmically repeated, subthreshold mechanical insults which, only by summation, lead to secondary changes.

As might be expected, such lesions often occur in patients who have just previously been confined to bed for several weeks for some other illness and in those who had been applied to duties for which at the time they were not fit, as in footballers who had been allowed to play after an interval of rest for some disability and young army recruits. In other words, undue stress to a bone of normal capacity or physiological stress to a bone of diminished capacity may result in such lesions. From the relative infrequency of this type of fracture the possibility of some disturbance of bone metabolism in addition to the trauma must be considered The condition of pseudarthrosis (see pp. 160 and 170) has additional features.

S M Roberts and *E C Vogt* in 1930 *J B Weaver* and *C F Francisco* in 1940 and *J B Hartley* in 1942, have published illustrated accounts of such fractures as they occurred in the upper third of the diaphyses in members of both sexes, the male markedly predominating in ages ranging from 4-84 years. Some were bilateral; some biopsies are recorded All healed without complications just as ordinary fractures. *W A Evans* has contributed a useful paper on recurrent fractures which deals with some of the preceding features.

The repercussion fractures of the vertebra which occur in convulsive therapy have been classed in the group of fatigue fractures but this opinion is questionable

recognised except by a fresh observer who is not obsessed with the traumatic evidence. Serial radiographic examinations of injuries to bone will give the earliest indication whether healing is proceeding with normal regularity or whether it is complicated by some underlying pathological process. In some cases the nature of the process will be suggested by the radiographic appearances.

The relation of trauma to malignant disease is discussed elsewhere (see Index)

Osteoporosis in Diabetes and Arteriosclerosis. The bones of the foot prior to the development of gangrene usually show a considerable degree of decalcification. As in the osteoporosis associated with adjacent sepsis this is probably associated with retention of some toxic substance rather than any increase in vascularity (see Fig 141 A).

PERIOSTITIS

Periostitis is indicated on the radiograph by a linear shadow running parallel and in close proximity to the surface of the bone the author refers to this appearance as a linear accretion of periosteal new bone It is more readily seen along the shaft of the long bones. Multiple laminated accretions may be shown as in a section through an onion. The thickness and definition of the bone is indicative of the degree of periosteal reaction and the chronicity of the lesion.

Radiographs which are taken with the film held in close contact with such superficial bones as the clavicle or lower end of the fibula frequently show an appearance which has been mistaken for evidence of periostitis. The parallel opacity represents the outline of the soft tissues in contact with the radiographic film and superficial to the bone. It is rendered visible by secondary radiation which produces slight fogging of the film where the latter is not protected by close contact with the soft tissues. It is the phenomenon which gives the apparent density to the nipples, skin papillomata breasts and male genital organs when these are radiographed in close contact with the film.

Traumatic ossifying periostitis of the new born has been reported in breech deliveries It is not seen for 7–20 days. Later the periosteal accretion is absorbed

In infants the chief causes for this appearance of the long bones are **Tuberculosis Congenital Syphilis, Scurvy Leukaemia, and certain Malignant Tumours.**

Inflammatory diseases of bone in infancy have a rather shorter latent negative radiographic period, the changes in the bone are thereafter more extensive but healing takes place more readily and complete resolution follows. This is well illustrated by Figs. 177 A and B Fig 177 A shows that in just over a week from the onset of symptoms in an infant of 2 months radiographs showed a linear periosteal involucrum surrounding the whole of the shafts of the tibia and fibula, and Fig 177 B, taken 6 weeks later shows the fibula lesion is beginning to subside but the tibia has become a dense and massive bone more than four times its normal calibre. *J Caffey* and *W A Silverman* have now investigated 10 children showing this type of reaction—they called it Infantile Cortical Hyperostoses. In their experience it occurs during the first 3 months of life in apparently healthy infants of healthy parents. The first thing noticed is often a swelling over an affected mandible but there may be one or more soft tissue swellings over other affected bones. The child may appear restless and irritable, perhaps tender over the swellings Fever 100 103 may persist, or like the swellings, fluctuate No local skin reaction The swellings appear to be considerable and of deep soft tissues In the face they may arouse the suspicion of parotitis. Radiography in the early days may fail to reveal any bone changes—the latent negative period—but later they will reveal one or more bo (mandible or other facial bones or base of skull, scapula, humerus radius ulna,

too may show a progressive decalcification, at first rather irregular in its distribution, giving the bone a mottled appearance

This condition, which was first described by *Sudeck*, is often referred to as acute *bone atrophy* a name which unfortunately does not readily occur to observers of this type of lesion, for it may persist for a number of years As the condition develops in but a small proportion of patients who have suffered traumata, some other factor such as focal sepsis, neuro-vascular disturbance or intoxication may be the influencing agent. The radiographic appearances during the progress of the lesion suggest that the bone changes are due to some disturbance in the trophic regulation of the part, and the reaction towards improvement, at any rate for a short time, which seems to follow sympathectomy appears to support this.

Where such changes follow traumata which have necessitated immobilisation, the radiographic appearances will be regarded as being due chiefly to disuse of the part and consequently will not occasion any serious reconsideration of the diagnosis, but in those cases in which the initial traumata have been given little or no prominence in the clinical history the progressive clinical signs and abnormal radiographic appearances may give rise to very serious errors in diagnosis unless the observers are familiar with the condition In some cases these clinical and radiographic signs have led to such grave diagnoses as bone tuberculosis, sarcomata, or other malignant changes and even amputation has been advised yet in other cases, the slow progression of the lesion, the vasomotor disturbance, and the appearance of disuse atrophy which accompany them have been regarded as evidence of malignancy Judging from the radiographs which have been referred to me for an opinion, it is particularly in the region of the larger joints, the knee, shoulder and elbow that these changes in the bone have been most confusing A number of these cases have been observed over several years, during which little or no improvement has been recorded on the radiograph, and the affected limb has become more and more disabled particularly in those patients who have lost faith in the benefits of physical medication. *Turner* claims to have obtained good results by iodine injections, while *Middleton* and *Bruce* found favour with acetylcholine. To instance the consequences of misinterpretation of such lesions the following brief account of a case submitted to me for an opinion is given.

Case Report. The patient developed a painful elbow and was sent for a radiographic examination. The radiographs revealed the changes seen in traumatic arthritis but these were attributed to tuberculosis and other more serious conditions, for which he received over a period of 3 years at the hands of various men in this country and many places on the continent courses of ultra violet irradiation, Hertzian irradiation deep X-ray therapy injections of tuberculin, iodine and mercury and an exploratory operation. In spite of all these interfering irritations the lesion presented surprisingly little change in the radiographic appearances and with a complete rest from all treatment I suggested that it might resolve.

Trauma and Focal Inflammatory Changes. It has been established experimentally that localised trauma to an animal with pathogenic organisms circulating in its blood can initiate the development of a bone abscess at the site of the trauma. Corroboration of this experimental evidence is abundantly obtained from examination of the histories of patients exhibiting localised acute or chronic inflammatory lesions Many cases of acute septic abscess, tuberculosis, or gummata of bone present clinical evidence of a primary septic, tuberculous, or syphilitic focus apart from the bone lesion which often appears to have originated at the site of a definite injury (see Figs. 88 A and B).

Because localised injury dominates t l picture in the early stages of the lesion, the superadded pathological chan ape discovery for weeks or months. Indeed, in some case ugh the nature ion may now be obvious, it is not

A series of radiographs has been published by *H B Jackson* which shows periostitis of the nora, tibiæ fibulæ ulnæ and radii of a girl aged 2½ years. This child showed a bulbous pansion of the ends of the fingers and toes, but no evidence of pulmonary disease syphilis leukæmia. He reports that the father and mother of the child were first cousins. The second th and seventh children were premature and died soon after birth. The patient was a sixth ild.

A miscarriage occurred between the second and third child. The first child suffers from eumatism the others are alive and well

The nature of this widespread periosteal thickening was not determined. Radiographically e appearances are unlike those seen in scurvy syphilis or leukæmia.

Le Wald [1] has recorded periosteal thickening of the femora in Erythroblastic Anæmia it this is not a constant finding

In the adolescent periosteal thickening is seen as the result of Trauma, Pyogenic ifections, Tuberculosis Gummata, Syphilitic Osteoperiostitis, Chronic Pulmonary Sepsis ulmonary hypertrophic osteoarthropathy (see p 55)) Periosteal Fibro-sarcoma, eriosteal Sarcoma, and Bone Endothelioma.

Dense bony excrescences and dense bands of sclerosed bone are seen in the condition escribed by *Léri* as melorheostose (see Fig 83) This is a localised bone dystrophy hich shows slow progression.

A spindle-shaped opacity having a flocculent appearance may be seen around one f the metatarsals, most commonly the second. No irregularity of the contour of the iaft may be seen. This appearance is due to calcification in a hæmatoma around the one. Frequently no definite history of trauma can be obtained, but subsequent conlidation and moulding, and in some cases the appearance of fracture indicate its aumatic origin (see Figs. 127 A and B).

It is of significance because the clinical and radiographic signs have been mistaken r those of sarcoma.

Bergstrand has illustrated such appearances around the second metatarsal of two irls aged 16 and 18 years. Both lesions were diagnosed as sarcomata and operated pon.

The clinical signs and symptoms of acute pyogenic bone infections are fortunately ifficiently typical for the establishment of the diagnosis, because the radiograph at his stage gives no indication that the infective process exists. Surgical measures have sually been adopted before the bone shows radiographic changes. The chronic lesion oes not give such a clear clinical picture, but in this case radiography will demonstrate, ither thickening of the periosteum, or in cases of localised bone abscess, evidence of entral cancellous destruction. In some cases both these changes may be indicated see Fig 174). The periosteum may be greatly thickened in chronic osteomyelitis and t may show striations perpendicular to the periphery of the shaft, but such striations re not seen until the chronic stage with sinuses to the surface has been well established They should not be confused with the fine, sharp linear striations of periosteal sarcoma see Fig 186)

The appearance of these lesions is discussed and illustrated by *Bromer Gwynne Williams Goldstein* and *Kurbangaleyev*

The Fibro-sarcoma usually does not show periosteal thickening until the lesion has ssumed large proportions. The trifling periosteal reaction as shown in the radiograph n contrast to the large tumour of the soft parts, serves to distinguish the lesion from steomyelitis, the condition with which it is apt to be confused, for both may be assoiated with a temperature and a history of trauma (see Figs. 66 A and B).

The radiographs published by *Kühne* and *Gerstel* show a most remarkable generalised periosteal thickening of all the bones of a youth aged 16 The patient was considered

pelvis, femur tibia and fibula) with linear periosteal accretions, usually thickest in the middle portion of the shaft of the long bones, and diminishing towards the extremities. The periphery may be irregular These accretions continue to be added until the bone takes on the appearance shown in Fig 177 B.

Radiography of the skeleton may show multiple lesions at sites which do not present any definite clinical signs and which would have otherwise been missed. The lesions appear to progress even up to 3 or 4 months—the ribs appear to show the quickest resolution. There may be remissions and recurrence of temperature and soft tissue swellings, but when the radiographic changes are most marked there may be little or no tenderness and the soft tissue changes may have subsided—the positive radiographic symptomless period.

Symptoms tend to disappear within 6 months and the progress is uneventful. At 5 years little or no sign of the lesions may be seen. The blood may reveal anæmia and perhaps increase in the serum phosphatase. All the other blood and urine tests are normal. No evidence of rickets, syphilis or scurvy the serial radiographic features of which are quite different. No organisms have been recovered at biopsy

Douglas Luckey and *Logan* have reported similar reactions in the scapula and adjacent clavicle in an infant aged 2 months. Nothing material to the ætiology was obtained from a biopsy The lesions almost completely resolved in 7 months. Except for one occasion, when the temperature reached 100·6 in rectum, it was not over 99·5 Massive reactions of this type are seen in some cases of tuberculous osteomyelitis (see Fig 90).

As shown in Figs 177 A and B though more than one bone is affected only one of them may show this dense and massive reaction.

A periosteal reaction associated with a localised area of cancellous absorption is often the first radiographic evidence of tuberculosis (see p. 71) It is a recurrent reaction which appears and disappears periodically with signs of activity

In Infantile Syphilis the periosteal bony accretions may double the thickness of the shaft They are associated with irregular sclerosis of the shaft and osteochondritis of the diaphyseal extremities (see Fig 165). Subperiosteal hæmorrhages may be seen during the first month of life

Scurvy Though it is generally considered that this disease occurs at a later period, the author has drawn attention to the fact that in infants even as early as the second or third month, one or more bones may show subperiosteal hæmorrhages These may be so extensive as to envelop the whole of a diaphysis. The tumour and the radiographic appearances produced have been mistaken for sarcoma. The author has seen ready response of these lesions to vitamin C with remarkable improvement in the infant's general condition. The case recorded by *Kane* and *Borsell* as infantile cortical hyperostoses would appear to be of this nature These may be more massive if the scurvy is associated with osteogenesis imperfecta (see Fig 470)

In Leukæmia periosteal lesions are more uniform and symmetrical and may be seen in all the long bones including the phalanges The blood picture of course will serve to differentiate any doubtful cases

Taylor has illustrated the radiographic appearances of Leukæmia of the long bones of the periosteum of a child aged 2 years 10 months His radiographs show elevation of the periosteum of all the metatarsals and metacarpals. A section of the tibia showed a lymphatic infiltration underneath the periosteum and also replacing the bone marrow (see also p. 65)

Karelitz has illustrated these appearances in the radiographs of the long bones of a boy aged 8 years. He also shows a similar appearance due to Periosteal Neuroblastoma infiltration, in the radiographs of the bones of a boy aged 2 years.

the pulmonary or the periosteal lesions are of a chronic inflammatory or neoplastic nature

Weinberger has published radiographs and photographs illustrating periosteal carcinomatosis secondary to Bronchial Carcinoma, and *Renander*[3] has illustrated a similar appearance in all the long bones due to metastases of a malignant adenoma of the suprarenal

In a few cases of carcinoma of the prostate the author has seen the bones invested in a fine spicular covering rather like the pile on plush.

Ernst Freund described an unusual form under the title of Idiopathic Familial Generalised Osteophytosis. The patient, a man of 57 recorded that 43 years ago 3 days after recovery from an attack of measles, the third and fourth fingers became swollen and tender and he was unable to move them. Recurrences occurred periodically for the next 8 years in other sites and after each bout the affected part did not return to normal. After this time the attacks became milder but most of the body was involved eventually No lesion could be detected in the heart and lungs. No changes in the blood. Both wrists and hands were slightly flexed and extremely enlarged, the skin showed hyper pigmentation. The fingers were clubbed, fusiform swellings of the first interphalangeal joints developed which were kept in extension. Marked swellings of the legs, ankles and feet were present Radiographs showed considerable periosteal new bone particularly around the joints The metacarpals and phalanges were very markedly thickened to twice their normal calibre. Bony spurs were present at the joint margins throughout the body The skull only appeared to be spared the peripheral overgrowth. He gives an account of similar cases recorded by *Hagner Ochme* and *Müller* The disease appears to start insidiously in the second decade of life

ACUTE OSTEOMYELITIS

Radiographic evidence of acute osteomyelitis for the purpose of diagnosis does not exist. By the time the bone shows changes detectable by radiography the shaft will have been denuded of periosteum and sequestra have formed. From radiographic examination of septic fingers, in which the date of onset can be more accurately fixed, I have determined that changes may be found in the affected bones within 10 days The earliest sign is localised osteoporosis, often first detectable in the cortex near the extremity of the diaphysis (remember this may be the first radiographic evidence of leukaemia). When the focus is situated in the medulla absorption of the cancellous structure may be evident. In less acute lesions no apparent change may be seen for 1 or 2 months, though there may be highly suggestive clinical signs and symptoms. In a patient aged 32, who had complained of pain in his leg for 1 month, radiographs revealed a well-defined area of cancellous destruction in the medulla of the tibia at the junction of the middle and upper thirds, with some increased density of the surrounding cortex. The subsequent changes following the acute infection depend on the relative virulence of the infection. In some cases (type 1) the infection appears to lead to thrombosis of elements of the nutrient vessels and a section of the bone and its periosteum may become necrotic neighbouring sections may not be so vitally affected and accordingly show evidence of reaction. These features may be brought out on the radiograph. The necrosed segment of bone will retain its normal shape for a considerable time while the adjacent bone will show progressive periosteal reaction by the deposition of new bone The periosteum may be destroyed *over only a section of the surface of the bone* and this will be associated with a corresponding surface which does not show a periosteal reaction. The necrotic segment of bone will show a progressive absorption, and being more friable, may fracture spontaneously leading with abolition of its function, to

to be suffering from lympho-sarcoma of the glands of the neck. Fifteen months after the illness began, his hands and feet began to swell. Metastases were also discovered in the lungs at post mortem.

Endothelioma of Bone produces a radiographic appearance which simulates that of chronic sepsis. The typical appearance consists of linear accretions of periosteal bone forming an onion-like covering to the primary focus but whenever this appearance is seen syphilis must first be excluded. Destruction of the central cancellous bone, widening of the medullary canal, and irregularity of the cancellous trabeculæ are additional confirmatory features (see Fig 228) The periosteal irregularity usually disappears after X radiation therapy

Gumma of a bone results in a localised thickening of the periosteum which may be seen on one aspect of the shaft only (see Fig. 225)

Syphilitic Osteoperiostitis is most commonly seen in the tibia. The bone is expanded, *has a forward convexity with an irregular surface and shows irregular sclerosis,* particularly at the extremities of the diaphyses (see Figs. 166–169) Any bone can be affected and show the appearances likely to be mistaken for *Ewing's* sarcoma (see Fig 117 A).

Chronic pulmonary sepsis may be seen in association with swelling of the joints, clubbed fingers and toes and thickened periosteum of the long bones (see Fig 55), the so-called **pulmonary hypertrophic osteoarthropathy** described by *Pierre Marie* and *Bamberger* Similar appearances of the fingers and toes have been seen in **congenital heart disease, ulcerative endocarditis, chronic jaundice, amyloid disease and biliary cirrhosis.** It was recorded by *E R Miller* in a boy of 14 with carcinoma of the thymus by *J A Roy* and *A. Jutras* in a man of 57 in association with thickening of the cranium, hypertrophy of the skin of the face and tarsal plates of the eyelids; by *C L. Martin* in cases of carcinoma of pharynx by the author who has seen it in several cases in association with carcinoma of the bronchus; by *R J L. Kennedy* in an infant of 7½ months.

The radiographs published by *Dale*[1] were of a patient suffering with a chronic empyema. They show periosteal thickening of all the long bones Further radiographs of the hands following draining of the empyema show that the thickened periosteal bone has been absorbed and normal characters established.

Fugelman has published the radiographs of a boy aged 8 years 2 months. This child began to get pain in the legs when 4 years of age. The radiographs show a spindle shaped thickening of the shafts of all the long bones except those of the hands and feet, the extremities retaining their normal appearance. The spleen was enlarged, but the other organs appeared to be normal. He suggests that the condition may be due to an uncommon blood disease, as a slight anæmia was present. *Hirsch* published a similar case.

In the Adult. Periosteal thickening in the adult is seen in cases of **Typhoid** and other **infections Pulmonary Hypertrophic Osteoarthropathy Osteomyelitis Tuberculosis, Syphilis** (see Fig 402), **Tropical Ulcer Yaws** and **Periosteal Sarcoma.**

Paschin has published the details and radiographs of two patients aged 30 and 45 years, who were suffering from chronic pulmonary tuberculosis. The radiographs show an extensive periostitis of a laminated nature involving all the long bones with the exception of the terminal and middle phalanges.

Radiographs of a man aged 28 which show similar lesions have been published by *Israelski* and *Pollack*, but in this patient no evidence of pulmonary nervous or syphilitic disease could be ascertained.

In some cases of **Bronchial Carcinoma** general subperiosteal proliferation occurs which results in radiographic appearances simulating those of pulmonary hypertrophic osteoarthropathy and it may be difficult to decide clinically or radiographically whether

onset of clinical signs. Such lesions may be due to different organisms. If tuberculous as a rule the localised destruction is soon followed by a progressive decalcification of the whole bone and the bones distal to it. Resolution is slow and often not complete. Though in a few cases it may be impossible to distinguish the site of the lesion, the bone being of normal structure; in most cases repair is with bone of coarser texture and a few dense granular deposits of calcium may be recognisable throughout the focus site

The typhoid and paratyphoid group of organisms may produce lesions which may be mistaken for those of tuberculosis. When the vertebral column is affected, the body may become osteoporotic and collapse and eventually built up again, leaving the discs entire throughout If the disc is attacked it is usually destroyed and adjacent bodies fuse. During the acute phase, when the dorsal and upper lumbar vertebræ are involved, a paraspinal abscess will be detected, but in the course of a month or so distinct from tubercle, this disappears. In the long bones chronic localised abscesses may persist which are associated with widespread dense reaction—such lesions have been styled Osteoid Osteoma (see p 180).

G Forssman has shown that the long bones affected in paratyphoid exhibit radiographic features in the destructive phase which are indistinguishable from the tuberculous lesion, but serial radiographs show rapid resolution. Lesions in infants under 4 months of age showed healing within the next 3 months

Subacute Osteomyelitis. In this physical signs and symptoms precede the development of radiographic signs by a week or more. Thus in a girl (D W) aged 10 years, radiographs taken 1 week after the onset of pronounced physical signs and symptoms showed a small ill-defined area of osteoporosis at the lower metaphyseal extremity of the tibial diaphysis, but a month later radiographs revealed irregular osteolysis of the whole of the lower third of the tibial diaphysis, including its compact cortex, and an accretion of new periosteal bone, which in places also exhibited calcium deficiency It was impossible to define the boundaries of the infected bone. Further radiographs after another month showed that calcium had been deposited, and there was now increased definition in the affected zone evidence of consolidation and localisation of the process, and more regular ossification of the new periosteal new bone. No evidence of sequestra formation could be found. This type, as in those preceding it, may go on to dense sclerosis of the whole affected segment of bone, or infection will persist for 20 or more years, resulting in sclerosis of the periphery with areas containing no bony structure representing the potential foci for recurrent bouts of activity or residual chronic abscesses

Chronic Bone Abscess. An account of the clinical findings in 8 cases of chronic bone abscess by *Sir Benjamin Brodie* and the radiographic and clinical findings in 62 cases investigated by the author [17] have been published.

There is perhaps no lesion in which the clinical history of the patient is more helpful in diagnosis than the Brodie abscess, and in introducing the question of differential diagnosis I cannot do better than quote Brodie's own words. He asks

"What are the circumstances that would lead you to suspect the existence of abscess in the tibia? The answer is, when the tibia is enlarged from a deposit of bone externally when there is excessive pain, such as may be supposed to depend on extreme tension, the pain being aggravated at intervals and these symptoms continue and become still further aggravated not yielding to medicines or other treatment that may be had recourse to, then you may reasonably suspect the existence of abscess in the centre of the bone.

The clinical history will indicate the age of the lesion and the existence of any previous septic focus of infection likely to be associated with bone abscess. Such information is invaluable in view of the fact that lesions of a widely different significance produce radiographic appearances which are rather alike. Such lesions are tuberculous

increased absorption. Whereas at the junction with the living bone during the course of 4–6 months there will be evidence of progressive substitution of the infarct. This is best shown by the advance of the periosteal new bone over the surface of the infarct. This type may be found in any of the long bones.

Type 2. This occurs more frequently in the middle third of the shafts of the humerus and femur. The affected segment will show some periosteal accretion of new bone with internal osteoporosis. During the second and third months disintegration of the middle third of the shaft occurs and fragments of the periosteal new bone may be carried away from the surface leaving it irregular while the surrounding soft tissues show the flakes which have broken away (see Fig 220). As the virulence of the infection dies down the surrounding bone will show increased calcium deposit and the detached fragments will be seen to be reunited by a less dense new bone to the original shaft, giving it a very irregular appearance; eventually a massive irregular involucrum will surround the original focus; in some cases with signs of an included segment which is necrotic, and for a time of greater density. This is the type of bone lesion seen in association with some cases of tropical ulcer (see p. 191).

Both types 1 and 2 present radiographic appearances at some time which may arouse the suspicions of sarcoma, especially when aborted by the sulphathiazole group or penicillin.

Type 3. In this type the area of the bone is rapidly decalcified and in this condition *it acquires an unusual plasticity so that it becomes deformed by pressure or muscular* action even during recumbent treatment. Multiple foci are frequently seen in this type. The lesions may resolve leaving the deformities to record the lesion, in other cases the bones continue to show marked decalcification. The shafts of the long bones may be enveloped in a broad but osteoporotic involucrum within which the original shaft becomes absorbed. While the milder examples of all these types may completely resolve, others go on to develop the characters of chronic osteomyelitis with irregular sclerosis, massive periosteal accretions, sequestra and residual abscesses.

As with periostitis, osteomyelitis in the newly born infant whatever the infecting pyogenic organism be, has a much shorter latent negative radiographic period, even less than one week, and thereafter the radiographic changes are marked. Most of the shaft which at first shows localised osteoporosis at the primary focus may be encased in a massive irregular involucrum of new bone, but, distinct from the later age periods, the illness does not appear to be so grave and complete resolution occurs in a relatively short time, though the lesions may be multiple. Within three or four weeks the wounds produced by surgical drainage heal and the definition of the new bone will indicate that the active phase has passed and from then on the involucrum is fairly rapidly absorbed. With increase in age the gravity of the localised lesions increases—the patient shows the clinical evidence of this and the radiographs may illustrate sequestration of the whole of the diaphysis or of multiple fragments. Early recognition and the prompt administration of sulphathiazole or penicillin may abort the lesions. The radiographs then show a small ill-defined area of osteoporosis at the primary focus with periosteal reaction, perhaps of the laminated accretion type and perhaps some fairly well-defined rounded organised calcium deposits in the adjacent soft tissues together with an added density of the bone away from the focus—appearances which have been mistaken for sarcoma when the previous clinical history has not been carefully taken.

Localised periostitis, osteitis, or osteomyelitis is associated with the radiographic appearances of localised periosteal new bone formation and a fairly well-defined area of destruction of bone. These appearances may not be present for 3 or 4 weeks after the

as an infectious disease in Burma, Siam, Malaya and associated countries. The disease resembles typhoid or cholera and has proved fatal as septicaemia within a few days or weeks. The chronic cases may be associated with localised destructive disease of bone, collapse of vertebral bodies leaving discs intact, and paravertebral abscesses which show readier resolution than those due to tuberculosis An illustrated account of these lesions is given by *J H Mayes*

Chronic Sub-periosteal Abscess. These lesions are less common than the chronic central bone abscess, and form a fairly well-defined group which possesses somewhat misleading clinical signs but characteristic radiographic and histological features. The outstanding clinical features are bouts of pain in the affected extremity these vary considerably in severity ; in some, amounting to little more than discomfort in others, sufficient to cause the patient to cease activity and to clench his teeth. A bout may be brought on by jarring the affected extremity This, however may exhibit no other sign of inflammation, neither localised heat, redness nor swelling There may be no elevation of the temperature. The absence of localised signs has in some cases led to the suspicion that the lesion was in the central nervous system and elaborate investigations, aimed at the detection of a displaced or prolapsed intervertebral disc, have been carried out. If the affected area of the bone is relatively superficial swelling may be noted, but the skin over the area will not show any change from the normal the subcutaneous tissues will not be increased and no undue tenderness to pressure may be recorded These symptoms develop insidiously and may persist for several years before the part is submitted to radiographic examination. When it is, the characteristic lesion is revealed. Though in a number of cases no history of localised trauma is given, in a few the history suggests that trauma has had an influence in its inception The lesions appear to be more frequent between the ages of 10–20 years but it may occur in adult life. The author [22] has given an illustrated account of 6 cases

Radiographic Appearances. These suggest that there is a lesion of bones which commences as a localised focus of irritation beneath the periosteum—notably in the long bones. From this focus, for a distance of 2 or more inches up and down the shafts of long bones, a periosteal reaction occurs. During the first 2 months this will be recognised on the radiographs from a linear accretion of new periosteal bone which is thickest at the site of the focus. The new bone for a time is less dense than the normal cortex which it covers, but gradually the latter appears to be absorbed into the new tissue Before it is completely absorbed the medullary outline of the original cortex, thin as a fine pencil line, can be detected by its slightly greater density except at the focus where it is totally absorbed Gradually during the next 3 or 4 months this periosteal new bone acquires density and receives accretions until the affected bone shows a dense spindle shaped expansion which merges imperceptibly into the normal shaft above and below *i.e., there is no line of demarcation* between normal and abnormal bone, though the extent of the lesion can be roughly estimated from the thickness of the cortex. At this stage all signs of the original cortex of that area covered by this periosteal new bone will have disappeared In the case of the long slender bones, like the ulna and radius, the periosteal reaction will extend completely around the shaft of the involved segment so that the spindle-shaped expansion is seen on all projections as in Fig 176 At its thickest part the expanded shaft may now measure more than twice the normal. In the case of the femur and tibia the periosteal accretion may cover only part of the circumference. At the site of the original focus a small well-defined rounded area of radiotranslucency will be seen. It is situated beneath the thickest part of the cortex and on a plane with the original periosteum. It persists throughout the development of the lesion, though in some cases it may be obscured by the density of the new bone. Even in such

abscess gumma, simple bone cyst, leukaemia, sarcoma and endothelioma. The chronic bone abscess at the diaphyseal extremity in the patient whose epiphysis has not yet fused is revealed on the radiograph by an area of cancellous destruction extending from the epiphyseal growth cartilage towards the medulla. Its boundaries are not sharply defined but they are perhaps rendered more apparent because the adjacent bone has an increased density. Frequently the lesion is spatulate in form, and even with 5 years history may be less than a ½ inch in thickness, but extending an inch or more from the epiphyseal line towards the medulla. The more acute the abscess the larger the cavity formed, the less defined are its boundaries and the greater the probability of new periosteal bone accretions.

As the lesion increases with age its boundary wall tends to become more sharply defined and sclerosed. In one patient, aged 21 who gave a history of a lesion of 17 years duration, the radiograph showed an abscess with a sharply defined regular wall, which was little more than ½ inch in diameter extending from the subarticular surface of the tibia for 1½ inches towards the medulla. In patients above 20 years of age, who give a history suggesting the beginning of an abscess about the age of 14 the radiographs may show the abscess to be about an inch above the ossified metaphyseal cartilage. It is rare for the growth cartilage to be penetrated by staphylococcal infection and the epiphyses eroded consequently though the joint may exhibit periodic effusion it is rare for it to be infected by extension but after the epiphysis has fused the lesion may be extended into the epiphyseal area and even infect the joint. No evidence of accretion of new periosteal bone may be found even after the abscess has existed many years: thus, in one of 17 years duration no thickening was apparent, and consequently no swelling was detectable on clinical examination. A linear accretion of periosteal new bone usually indicates renewed activity. It may be absorbed during a further period of quiescence. However in those cases in which the abscess has involved most of the diaphyseal extremity an accretion of new periosteal bone will be shown. No sequestrum is to be observed within the abscess cavity except in those cases that have been subjected to surgical intervention, as the abscess extends by the gradual absorption of the adjacent bone. Much less common than the abscess in the metaphyseal region is the abscess in the middle third of the shaft of a long bone and beneath the periosteum.

Medullary Abscesses. An abscess in the medulla of the middle third of the shaft of a long bone is recognised from its radiographic appearances. The shaft in the area shows, in some cases, a spindle-shaped expansion or thickening. In the middle of the expanded segment a well-defined rounded or ovoid area of cancellous destruction—the abscess cavity—is seen. This area is surrounded by a thick wall of dense compact bone which appears to obliterate the medullary cavity above and below the abscess cavity. Surrounding the thickened abscess wall, evidence of activity is indicated by the thin regular layer of new bone that is being added beneath the periosteum. Following successful surgical evacuation of the abscess cavity the bone assumes its normal compact and cancellous proportions, the reactive periosteal bone being absorbed.

Large medullary abscesses may develop with little reaction or change in the contour of the bone (see Fig. 496).

In some cases when localised excavation of the bone failed to reveal the abscess, resolution has occurred. Such lesions can be accurately localised for the surgeon—a procedure which should be encouraged for then accurate surgery can completely evacuate the abscess in the minimum of time.

Chronic Melioidosis regarded as being due to *Bacillus Whitmori* may be associated with multiple bone lesions liable to be mistaken for those of tuberculosis. The disease is more acute and can be recognised by identification of the causal organism. It occurs

as an infectious disease in Burma Siam, Malaya and associated countries. The disease resembles typhoid or cholera and has proved fatal as septicaemia within a few days or weeks. The chronic cases may be associated with localised destructive disease of bone, collapse of vertebral bodies leaving discs intact, and paravertebral abscesses which show readier resolution than those due to tuberculosis An illustrated account of these lesions is given by *J H Mayer*

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Radiographic Appearances. These suggest that there is a lesion of bones which commences as a localised focus of irritation beneath the periosteum—notably in the long bones. From this focus, for a distance of 2 or more inches up and down the shafts of long bones, a periosteal reaction occurs. During the first 2 months this will be recognised on the radiographs from a linear accretion of new periosteal bone which is thickest at the site of the focus. The new bone for a time is less dense than the normal cortex which it covers, but gradually the latter appears to be absorbed into the new tissue. Before it is completely absorbed the medullary outline of the original cortex, thin as a fine pencil line, can be detected by its slightly greater density except at the focus where it is totally absorbed. Gradually during the next 3 or 4 months this periosteal new bone acquires density and receives accretions until the affected bone shows a dense spindle shaped expansion which merges imperceptibly into the normal shaft above and below i.e., there is no line of demarcation between normal and abnormal bone, though the extent of the lesion can be roughly estimated from the thickness of the cortex. At this stage all signs of the original cortex of that area covered by this periosteal new bone will have disappeared. In the case of the long slender bones, like the ulna and radius, the periosteal reaction will extend completely around the shaft of the involved segment so that the spindle-shaped expansion is seen on all projections, as in Fig 176 At its thickest part the expanded shaft may now measure more than twice the normal. In the case of the femur and tibia the periosteal accretion may cover only part of the circumference. At the site of the original focus a small well-defined rounded area of radiotranslucency will be seen. It is situated beneath the thickest part of the cortex and on a plane with the original periosteum. It persists throughout the development of the lesion though in some cases it may be obscured by the density of the new bone Even in such

abscess gumma, simple bone cyst, leukæmia sarcoma and endothelioma. The chronic bone abscess at the diaphyseal extremity in the patient whose epiphyses has not yet fused is revealed on the radiograph by an area of cancellous destruction extending from the epiphyseal growth cartilage towards the medulla. Its boundaries are not sharply defined, but they are perhaps rendered more apparent because the adjacent bone has an increased density. Frequently the lesion is spatulate in form, and even with 5 years history may be less than a ¼ inch in thickness, but extending an inch or more from the epiphyseal line towards the medulla. The more acute the abscess the larger the cavity formed, the less defined are its boundaries and the greater the probability of new periosteal bone accretions.

As the lesion increases with age its boundary wall tends to become more sharply defined and sclerosed. In one patient, aged 21 who gave a history of a lesion of 17 years duration, the radiograph showed an abscess with a sharply defined regular wall, which was little more than ½ inch in diameter extending from the subarticular surface of the tibia for 1½ inches towards the medulla. In patients above 20 years of age, who give a history suggesting the beginning of an abscess about the age of 14 the radiographs may show the abscess to be about an inch above the ossified metaphyseal cartilage. It is rare for the growth cartilage to be penetrated by staphylococcal infection and the epiphyses eroded consequently though the joint may exhibit periodic effusion it is rare for it to be infected by extension but after the epiphysis has fused the lesion may be extended into the epiphyseal area and even infect the joint. No evidence of accretion of new periosteal bone may be found even after the abscess has existed many years: thus, in one of 17 years duration no thickening was apparent, and consequently no swelling was detectable on clinical examination. A linear accretion of periosteal new bone usually indicates renewed activity. It may be absorbed during a further period of quiescence. However in those cases in which the abscess has involved most of the diaphyseal extremity an accretion of new periosteal bone will be shown. No sequestrum is to be observed within the abscess cavity except in those cases that have been subjected to surgical intervention, as the abscess extends by the gradual absorption of the adjacent bone. Much less common than the abscess in the metaphyseal region is the abscess in the middle third of the shaft of a long bone and beneath the periosteum.

Medullary Abscesses. An abscess in the medulla of the middle third of the shaft of a long bone is recognised from its radiographic appearances. The shaft in the area shows, in some cases a spindle-shaped expansion or thickening. In the middle of the expanded segment a well-defined rounded or ovoid area of cancellous destruction—the abscess cavity—is seen. This area is surrounded by a thick wall of dense compact bone, which appears to obliterate the medullary cavity above and below the abscess cavity. Surrounding the thickened abscess wall, evidence of activity is indicated by the thin regular layer of new bone that is being added beneath the periosteum. Following successful surgical evacuation of the abscess cavity the bone assumes its normal compact and cancellous proportions, the reactive periosteal bone being absorbed.

Large medullary abscesses may develop with little reaction or change in the contour of the bone (see Fig 406)

In some cases when localised excavation of the bone failed to reveal the abscess, resolution has occurred. Such lesions can be accurately localised for the surgeon—a procedure which should be encouraged for then accurate surgery can completely evacuate the abscess in the minimum of time.

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this reaction as associated with infiltration of this bone by malignant cells. No evidence of such infiltration can be seen in the histological structure of the so-called "osteoid osteoma." Further though resection, which removes only the primary focus of the latter lesion and leaves the reactive tissue surrounding it, will be followed by healing resection of this nature in the case of a bone tumour will be followed by further development of the tumour

If we study the cases described by *Jaffe* and *Lichtenstein* we find that they include some which possess entirely different radiographic appearances though similar histological characters. These lesions are situated in the cancellous structure and not subperiosteal. They do not present the radiographic appearance of localised bone sepsis, and are conceivably of the nature of bone tumours with a central rounded sequestrum. The histology in some of these may in part be regarded as showing malignant characters—it was such findings which prompted amputation of the right arm of a girl the radiograph of whose humerus showed such a benign tumour with a rounded central sequestrum. The radiographs and details of this case published by the author [22] show the typical appearances described by *Jaffe* and *Lichtenstein* (see Fig 400) The simplicity *of the lesion is supported by the subsequent clinical history of good health and no* recurrence.

BONE CYSTS

Radiographs of the bones show a variety of cyst-like structures which may be separated into the following groups —

(1) Cysts which arise at the site of bone injuries, the most frequent example being cysts in the carpal scaphoid

(2) Simple bone cysts near the extremities of the long bones.

(3) Cysts due to infection—the dental cysts being the most common.

(4) Degenerative cysts in the subarticular bone of osteoarthritic joints.

(5) Localised osteitis fibrosa cystica, *i.e* polycystic dystrophy of bones.

(6) Cysts in generalised bone disease. (Hyperparathyroidism, osteitis deformans, osteomalacia, renal rickets type II osteogenesis imperfecta.)

(7) Cyst like appearances due to tumours in bone

(8) Parasitic cysts. Hydatid.

(9) Dentigerous cysts.

(10) The localised expanded cyst like lesions of polyostotic fibrous dysplasia.

The existence of any of these lesions may be brought to light by the radiography of the affected bone undertaken to ascertain the cause of a spontaneous fracture, a deformity or pain.

Traumatic Cysts. Radiographs of a bone which has been recently injured may show no evidence of fracture but further radiographs taken after an interval of a few weeks may show a rounded area in the bone from which the cancellous tissue has been absorbed. This is a frequent finding after injury to the scaphoid, and an illustration is given in Fig 80

Similar areas have been seen in other cancellous bones following trauma. In a patient who had had an injury to the external malleolus 12 years previously a radiograph showed an ovoid cyst-like structure in that area. Radiographs were taken at 3 monthly intervals but no appreciable change should be detected in 6 months. The author found such areas in all the carpal bones and the heads of the metacarpal bones of men working with compressed-air drills (see Fig 50).

Bloodgood has described a cyst-like structure at the site of an old fracture of the femur in a boy of 20 years

cases it may be revealed by using greater penetration in taking the radiograph. The outer surface of the spindle-like expansion is smooth and it gradually blends into the regular outline of the normal cortex of the shaft above and below (see Fig 225). In the case of those bones which are relatively superficial, such as the ulna, radius or tibia, the position of the lesion can be judged from a noticeable swelling of the area. The soft tissue on the swelling is not increased in bulk or altered in density or texture

Treatment. Localised resection of the cortex, including the irritant focus, which is usually within the thickest part of the dense new cortex, will usually lead to healing of the lesion and disappearance of the symptoms of which the patient complained. Examination of the resected fragment will reveal a small well-defined rounded focus containing at one stage osteoid tissue which in the later stages may be more or less calcified. Histologically the appearances are typical they have been well illustrated and described by *Jaffe* and *Lichtenstein*.

Nature of the Lesion. They have described the lesion as an *osteoid osteoma*—a benign osteogenic tumour of slow growth which incites the tissue around it to an extensive reactive formation of new bone The presence of rather large amounts of osteoid is characteristic of the lesion at one stage in its evolution—subsequently this becomes calcified and converted into hypercalcified bone which is neither typical fibrous bone nor typical lamellar bone. When fully evolved, the lesion is composed of compacted trabeculæ of this atypical bone, the intra trabecular tissue is vascular and may still be *rather cellular in some places. Ultimately they state, it is the osteoma rather than the* osteoid aspect of the lesion that is conspicuous microscopically *Jaffe* and *Lichtenstein* also state that the radiographic picture is most commonly mislabelled chronic sclerosing non-suppurative osteomyelitis," "intracortical abscess," "syphilitic osteoperiostitis," or even less plausibly sclerosing osteogenic sarcoma," or when it occurs near an articular surface, "osteochondritis dissecans."

The serial radiographic appearances are such as one would expect to find as the *result of a localised chronic sub-periosteal focus of infection from which toxins are* produced and diffused throughout the immediate neighbourhood The resemblance to the radiographic appearances of certain chronic bone abscesses is so strong as to cast a doubt on any other interpretation (see Figs 176, 223 and 400) In the latter lesion, when due to certain types of infection, the focus, while containing the organisms, continues as an unossified cavity within the expanded reactive bone, as will be seen in the case of the chronic abscess illustrated in Fig 224 from which a pure culture of Bacillus *typhosus was cultivated. In 2 cases staphylococci were cultivated from the central* focus In those cases of *Jaffe* and *Lichtenstein*, from which staphylococci were cultivated they were regarded as contaminations. Three cases have not received any operative treatment, but 1 case was a congenital syphilitic and the lesion was regarded as a gumma, for it responded to some extent to antisyphilitic medication. This does not exclude the possibility that the lesion was produced by other organisms than the *T Pallida*, but it does lend support to the view that the lesion is of a chronic inflammatory nature. *Certainly chronic syphilitic periostitis bears some resemblance to these lesions.*

Though the histological appearances, as illustrated and described by *Jaffe* and *Lichtenstein* lend support to their suggestion that it is a benign tumour of bone there is nothing in the radiographic appearances which supports this diagnosis. No known benign tumour of bone produces reaction distal to the wall of the tumour the boundaries between such lesions as simple and multilocular cysts, fibroma, myxoma, angioma, chondroma and osteoma, and the surrounding normal bone are clearly defined. On the other hand *certain malignant tumours of bone, both primary and secondary* are sometimes associated with reaction in the adjacent bone but histological examination reveals

ditions of bone are discovered by radiography it may be found by radiography of skeleton that other isolated lesions of a similar nature are present without local signs ymptoms In some cases they involve the whole segment—in others but a section he cortex, generally near to the growing extremity In the young patient they are in association with the latter and continue to grow with the patient but once the wth cartilage is completely walled in by bone the cyst progressively travels away n it and tends to diminish in size (see Fig 84 A and B). These localised lesions overed accidentally by radiography following injury are sometimes mistaken for e serious pathological conditions. Even the histology may be interpreted as such.

Cysts due to Infection. The commonest cyst due to infection is seen at the apices nfected teeth. These vary considerably in size. In some cases the whole of one side he mandible or maxilla may be excavated. The radiographic appearances of large ts of this nature in the maxilla are apt to be wrongly interpreted as loculi of the antrum. infecting tooth or its apex may be present, but in some cases the cyst continues to elop after the tooth is extracted until a more extensive exposure is made (see s. 463 and 464).

In rheumatoid arthritis localised destruction of the cancellous tissue may occur the subarticular bone. Such areas have a cyst-like appearance. In the region of hip-joint, either above the roof of the acetabulum or in the femoral head, these nded areas of cancellous destruction may reach the size of a hen's egg Following ion of the symphysis pubis a similar process may produce the appearances of a ge ovoid foramen in the central area. In the carpus complete destruction of the ernal cancellous structure of one or more bones may leave but a shell which shows prisingly little reaction until accidentally broken. Such lesions the author has erved in the infant carpal bones in Still's disease

The cyst like areas which develop in the subarticular bone of the osteoarthritic nt are usually small and multiple, but in some cases much larger areas of destruction found.

Circumscribed areas of cancellous destruction in the long bones may be due to h conditions as a focus of **Sepsis** (see Figs 176 and 496) **Tuberculosis Sporotrichosis Coccidiosis Lipoid granulomatosis, a Gumma,** or an early **Neoplasm.** The radio- phs published by *Altschul* [1] of a woman, aged 62, show a multilocular cyst of the ndible and similar changes in the skull, clavicles, ribs and femur due to orotrichosis.

Campbell [1] has published a radiograph of a gumma of the femur which shows the pearance of a central cyst. A **Brodie's Abscess** may produce a similar appearance e Figs. 176 and 496)

Degenerative Cysts. In the subarticular bone in Still's disease rheumatoid arthritis d osteoarthritis cyst like changes frequently develop. These contain a gelatinous ucoid material which probably arises from degeneration of the bone structure.

All the cancellous tissue *from within carpal bones may be absorbed,* while the region of the hip-joint cysts as large as a hen's egg have been seen in these nditions

Fischer has suggested that they are caused by amoeba, while *Thompson* suggests at helminthes may be responsible. There is no histological evidence to support either these suggestions.

The suggestion of *Lacford Knaggs,* [1] that they are due to the effect of toxins, is the ost probable, though trauma may also play a part in their development.

Localised Osteitis Fibrosa Cystica. In this condition a circumscribed area of the nes may present a multilocular cyst like appearance. Such areas have been

Elmslie curetted such a cyst in a girl of 18 years.

Bilton and *Pollard's* specimen in the Museum of the Royal College of Surgeons shows a cyst in the tibia from a girl aged 5 years who had had an injury to the bone in early infancy.

Simple Bone Cysts. Simple bone cysts are frequently seen in the upper end of the femur, humerus, and the mandible, and less frequently in the lower end of the radius, and upper and lower ends of the tibia; examples are illustrated in Figs. 167 A and B and 226 A and B. The origin of these cysts is not definitely established.

Lanford Knaggs[1] states that an injurious influence is exerted upon the bone by toxins which may be derived from one or more of various sources. *Pommer* and *Looser*[2] are of the opinion that such cysts are due to trauma which causes intra-osseous hæmorrhage. The pressure of the blood and serum within the resistant compact cortex leads to absorption of the cancellous bone. The injured tissues excite further inflammatory exudation and the cyst gradually expands. This theory is supported by the fact that these cysts usually contain altered blood or serum and consolidation frequently occurs after spontaneous fracture. We also know that similar cysts develop at the site of definite injury. *Geschickter* and *Copeland* are of the opinion that giant-cell tumours, osteitis fibrosa and bone cysts are different phases of a definite pathological variation in the reparative process of bones and that these lesions are definitely associated with trauma. They occur at ages during which normal bone is most active and in locations most subject to trauma—namely, the upper and lower ends of the femur, the upper end of the tibia and humerus, and the lower end of the radius. They consider that this pathological variation is the result of an imbalance in two normal repair processes—*i.e.*, osteoclastic giant-cell proliferation and the formation of new bone directly from fibroblasts.

Several cases have been seen by the author in which the development of the cyst has ceased and subsequent calcification has occurred. Following surgical evacuation and curettage, such cysts usually consolidate. It is conceivable if the theory of *Pommer* and *Looser* is correct that consolidation would follow simple drainage of the cyst. In one case, a man of 45, malignant metaplasia occurred at the site of a simple cyst in the humerus which had consolidated following fracture 20 years previously. Clinically, radiologically and histologically it appeared a typical sarcoma. X radiation, followed by amputation, was not followed by a recurrence in 7 years.

The author has watched the development of several of these simple cysts in the diaphyseal extremity at the level of the growth cartilage. They appeared to increase in size while so placed but when once bone was laid down which separated the cyst from the cartilage no further development of the cyst occurred and by the growth of new bone at the metaphysis the cyst appeared to travel away from the latter. This feature was not seen in the multilocular cyst which continued to grow though not in contact with the metaphysis; such cysts are found more commonly in the intertrochanteric area of the femur and the upper end of the humeral diaphysis (see Figs. 227 and 118).

In one case in the author's series a multilocular cyst in the intertrochanteric area of the femur was curetted and filled with bone chippings but it continued to show progressive development. Later *Mr. A. M. Hendry* resected the whole segment of the bone which contained the multilocular cyst. He found its walls hard and apparently sufficient for normal function. He bridged the gap with a section of the fibula, and now 10 years later this graft has developed into the size and shape of the normal femoral shaft (see Fig. 227). A similar cyst in a case described by *Andreasen* gradually resolved without any surgical interference (see p. 228). When one of these multilocular cystic

ARTHRITIS

The radiographic appearances of the joints in rheumatoid, gonococcal, and osteo-arthritis are illustrated and described in the first part of the book.

Rheumatoid arthritis shows its greatest incidence in women between the ages of 40–45 years. It is associated with an accelerated sedimentation rate as is also acute rheumatic fever and the acute phase of gout. In osteoarthritis and fibrositis and in the early stage of rheumatoid arthritis the sedimentation rate is usually normal.

The Sedimentation Rate using the Westergren technique shows a normal range of setting of from 1–3 mm. per hour in men and from 4–7 mm. per hour in women. Figures from 8–15 are referred to as a slightly accelerated rate, from 15–40 a moderately accelerated rate and from 80–100 an extremely accelerated rate.

Arthritis set up by trauma may ultimately completely resolve, leaving no radiographic evidence of past damage. In acute infective arthritis the joint space is increased by effusion into the joint which separates the articular surfaces. If severe the bones show osteoporosis and the articular surfaces may lose their sharp definition and become woolly in appearance. This condition may completely resolve and the bones assume a normal radiographic appearance, but, in other cases, the damage to the articular surface is more severe and the radiographic signs of a chronic arthritis begin to appear. The joint space is gradually diminished. The bone shows an increased density and the articular surfaces, now irregular in outline, become more clearly defined. Ultimately the radiographs show sclerosis of the bone extremities which are now in close apposition, indicating destruction of the articular cartilage. Finally the joint shows the typical appearances of a secondary osteoarthritis. Arthritic changes associated with marked irregularity and disturbance of growth at the epiphyseal line of the long bones of the forearm are not an infrequent complication in small pox in children under the age of 12. These lesions result in marked deformities of the limbs owing to the unequal growth of the radius and ulna. Either may be dislocated at the wrist or elbow. The radiographic appearances of these lesions is not unlike those seen in some cases of chondro-osteo-dystrophy.

Cathcart, *Huenekens* and *Rigler*, *Lombard* and *F. B. Sheldon*, have published radiographs and details of these cases.

Kienböck [2] has published a series of radiographs illustrating a severe infantile poly-arthritis which began when the child was 8 years of age. Marked irregularities of the growing ends are shown which led to the condition being called pseudo-achondroplasia.

An endemic form of polyarticular bone disease was first reported by *Kaschin* in 1861 in the inhabitants of the Urow valley. Lesions are commonest in the inter-phalangeal joints, but the knee, wrist and ankle joints are frequently affected. The hip and shoulder joints are seldom affected. The illness begins insidiously about the age of 5 years, without discomfort, fever or any signs of inflammation. During the course of 8 to 10 years, growth of the long bones is checked and most of the joints become involved and present the radiographic appearance of a chronic arthritis.

Beck expressed the opinion that the condition was due to drinking the water of the Urow river. Other authorities have suggested endocrine dyscrasia and avitaminosis as the cause.

Goldstein and *Nikiforov* have described a similar condition in a man aged 40 and his two sons aged 18 and 3½ years, in the region of Mari. The radiographs show atrophy and osteoporosis associated with polygonal deformities of the joint surfaces and adjacent epiphyseal extremities of the long bones. The metacarpals, metatarsals and phalanges are thickened. Changes suggestive of osteitis are also seen in the vertebræ and skull.

in most of the long bones, the vertebræ and the skull, and are referred to in the chapters dealing with the anatomical distribution of bone lesions. Such lesions are usually progressive, and even when the cystic area is excavated and curetted the new bone may undergo a similar change, as in the case of the tibia illustrated in Fig 179. Multiple foci may be present in the skeleton but the other bones and even the adjacent bone are normal in structure and density—this distinguishes it from hyperparathyroidism (see p 597). The author regards the lesions as a polycystic Dystrophy of Bones

Cystic Appearance of the Bones in Generalised Bone Disease. In most of the generalised bone diseases particularly hyperparathyroidism, myelomatosis, osteitis deformans multiple chondromata, polyostotic fibrous dysplasia, polycystic dysplasia, some cancellous areas show absorption of the trabeculæ and the formation of cyst-like areas but the radiographic appearance of the other bones usually suffices to establish the diagnosis

Cyst-like Bone Change due to Tumours. Circumscribed areas of cancellous destruction resembling cysts may be seen in bones as the result of such tumours as **Chondroma, Myxoma, Fibroma, Adamantinoma Myeloma, Osteoclastoma Plasmocytoma, Sarcoma and Secondary Carcinoma.**

In *Platt's* [1] paper will be found a series of radiographs illustrating some of these conditions

Cyst like appearances of the bones in von Recklinghausen's Neurofibromatosis are shown in the illustrations published in the papers of *Brooks* and *Lehman* and *Parkes Weber* [2]

Hydatid Cysts of Bone (see Fig 186 p 187) Hydatid cysts in bone are uncommon. The invaded bone shows a progressive destruction at the site of the cyst which often has a multilocular appearance. The bony walls show a reactive sclerosis Small amorphous deposits of calcium may be seen within the cystic area. The nature of the lesion in most of the published cases has not been established for many years, by which time the parasite has destroyed large areas of the bone and the possibility of cure has been lost.

The author [16] published a radiograph of a hydatid cyst of the mediastinum which had been mistaken, and treated in a sanatorium as a tuberculous abscess. It ultimately eroded the vertebræ and caused death by involving the spinal canal (see Fig 187).

The commonest bones affected are the pelvis and the femora.

Bauer published the radiograph of a hydatid cyst of the tibia.

Meyer's radiograph shows a cystic condition of the first rib which caused lower arm (Klumpke) paralysis. Ecchinococcal cysts were found in the rib at operation.

In one of the author's cases a cyst involved the lumbo-sacral area of the spine and caused dislocation.

A similar case has been published by *R S Stone* in which subsequent cysts were found in the spinal canal.

Details of other cases with radiographs have been published by *Akelrod Bauer B L. Coley Fränkel* and *Pytel Hsieh, Kienböck*, and *Meyer*

Dentigerous Cysts. Dentigerous cysts are most frequently seen in the region of the angle of the mandible. They are to be distinguished from the dental cyst and the large "blood" cysts which are encountered in this area, by the presence of a number of denticles Smaller specimens containing single denticles are not infrequent in the upper canine area. The possibility that such cysts may have become infected should not be overlooked or disaster may follow surgical interference (see p 503)

Implantation dermoid cysts are occasionally seen in the bones of the hand (see Fig 48 A) Dermoid cysts containing teeth (as in Fig 338 B) may be shown within the skull.



FIG. 484A.



FIG. 484B.

FIG. 484 A and B. Alkaptonuria. Note destruction of all discs and both hip joints. Characteristic changes.

The joint changes were never associated with the development of abscesses and did not lead to ankylosis.

Further radiographs illustrating the lesions in 4 patients suffering with this disease are published by *Mickallar*.

In the early stages of joint destruction in Psoriasis some degree of osteoporosis may be present but later the bones affected appear to acquire an added density. Later the joint space is diminished and this is followed by erosion of the joint surfaces and atrophy of the shafts which produce a thorn-like appearance to the bony extremities.

Later the destruction of the expanded extremities of the bones entering into the joints may be so complete that the shafts and opposing ends of the bones may be atrophied and tapered; the digits may appear to be telescoped. The most remarkable instance of this type of joint destruction was published by *H. Cohen*. All the bones and joints of the extremities showed profound atrophy and destruction giving a spider-leg-like appearance to all the extremities. The cause of the condition had not been determined but the resemblance to the less extensive lesions in psoriasis suggest that the underlying cause, possibly neurotropic, was similar. *Rocklin* and *Schirmunsky's* article shows examples of the bone and joint changes found in psoriasis.

Patients with hæmophilia are prone to hæmarthrosis with resultant secondary changes in the bones. The affected joint becomes swollen and painful, and its movements are much limited. The first radiographic appearance is an increase in the joint space, followed by expansion, due to erosion, of the non-articular surface of the joint at the site of interarticular ligamentous attachments, *e.g.*, the fovea of the femoral head and the intercondylar area of the lower end of the femur. Cyst-like areas of cancellous destruction may then appear in the subarticular bone; these are usually well-defined though in bone which is osteoporotic their margins are not so well defined—the extent of the latter is determined by the extent of enforced immobility. The articular surface covering these may be absorbed and marked irregularity of the articular surface results. The diaphyseal extremities of the bones usually exhibit multiple transverse lines. These changes may develop at an early age. The epiphyseal ossification may be disturbed and changes simulating osteochondritis may appear. At a relatively early age, as a result of the destructive changes, the joint takes on the appearance of severe secondary osteoarthritis. For pseudo-sarcoma in hæmophilia see p. 218.

Fractures in hæmophilia may be associated with considerable sub-periosteal hæmorrhage which may not be apparent until ossification—this may persist for a long time. Multiple hæmarthroses may occur without any radiographic evidence of change.

Evidence of growth disturbance is shown later by asymmetry of the limbs. Examples are illustrated by *Klaron*, *Farfola* and *Prip Buus*.

Osteoarthrosis Alcaptonuria (Ochronotica) or chondrosis dissecans ochronotica. This condition is recognised clinically by the urine gradually turning a dark colour though voided apparently normal. It is darkened by adding alkali and transiently turned blue on the addition of a weak solution of ferric chloride. The cartilage of the ears may appear darkened—some dark spots may be seen in the sclerotics. The disease is relatively benign and slow in progress. Pigment is deposited in cartilage and in the intervertebral discs. These gradually degenerate and become compressed and friable. Fragments break off from the articular surface; the capsule of the joints is irritated and becomes thickened—the bony surfaces are approximated and ultimately come into contact, then they may show some degree of splaying out; perhaps some localised excavations; detached fragments of the articular surface may show proliferation and form capsular osteomata. The joint movements become restricted and ultimately fixed by ossification of the capsule and ligaments. The vertebral column shows atrophy and

In the case illustrated by *Saupe* the radiographs show collapse of some vertebral bodies, and erosion of others, as in aneurysm by pressure from the enlarged glands.

Radiographs and details of further cases have been published by *Barron Montgomery Ginsburg* [1] *Kremser* [1] *Grudzinski* [1] *Friedrich*,[1] *Hülten* and *Arnell, Belot, Nahan* and *Kimpel*.

BONE CHANGES IN BLOOD DISEASES ETC.

Osteo-myelo-sclerosis in anæmia, leukæmia and aleukæmic leukæmia see p. 557

Congenital Anæmia. *Cooley* has described and illustrated the radiographic appearances of the bony changes which occur in splenomegalic erythroblastic anæmias in children.

The radiographs of the skull show marked thickening of the cancellous diploic bone with closely packed fine trabeculæ radiating perpendicularly from the plane of the inner table (see Fig 434) Both tables appear to be much thinner than normal, and in some cases the outline of the outer table is obliterated. All the bones show osteoporosis coarse cancellous trabeculation and reduction in the thickness of the compact cortex. No periosteal thickening or joint changes are reported, except in *Le Wald's* [1] case Recently in a paper reviewing the evidence on **Erythroblastic Anæmia**, *J M Flynn* included an account of a child aged 8 years The radiographs of the skull show the fine spicular development, the long bones appear to be generally expanded and osteoporotic. They have no compact tissue but the periphery is clearly defined by a linear shell. They have none of the exquisite architecture of the normal either externally or internally

Mandeville Vogt and *Diamont* report expansion of the long bones.

In a case seen by the author which showed these skull changes it was established that the condition was not Cooley's anæmia.

Leukæmia and Chloroma. The bone changes may be so slight that they are over looked but in other cases they may be profound.

The condition may be suggested by bluish discolorations of the skin which vary in size from pin-point to large bruises. Attention to an abnormal condition of the patient may be drawn by a persistent hæmorrhage following tooth extraction. The child may appear pallid have attacks of vomiting lose weight, complain of pain in the back or limbs and exhibit localised tenderness over one or more bones. The liver may be enlarged

Acute leukæmia of the infant may be indicated by the radiographic appearance of periosteal thickening of the long bones, including the metacarpals, metatarsals and phalanges. Linear periosteal accretions, single or multiple, along a portion or whole of one side or as an involucrum to the whole of the diaphysis of a long bone, leaving a linear translucent area between it and the original cortex Such an appearance in an infant should prompt investigation for leukæmia. Localised ill-defined areas of decalcification may also appear in the shaft, and the cortex may in part or in a large measure, be absorbed The histology of a section through a bone showed a lymphatic infiltration underneath the periosteum and replacement of the bone marrow by similar tissue.

Rolleston and *Frankau* reported the findings of a case in which the clinical features simulated those of Pott's disease

Radiographs of the infant may show changes which may be mistaken for those of scurvy marked osteoporosis in some cases this may be so profound that the outline of part of a bone may be difficult to define. The metaphysis is expanded by a zone of osteoid tissue, and in association with this disintegration and displacement may occur between the diaphysis and epiphysis. Or if this does not occur the acute phase may be indicated later by a broad zone of osteoid some distance from the extremity

destruction of discs the remnants of which become calcified the bodies showing little deformity apart from slight splaying and bridging—a characteristic picture. The hip, shoulder or any other joints may be affected, the changes usually being symmetrically destroyed. The complete destruction of the cartilage, the close apposition of the bony surfaces and the splaying out of these surfaces is very characteristic in the well-established case (see Figs 484 A and B).

Bauer and *Kienböck* publish the radiographs of a man aged 54 years who had alkaptonuria. The radiographs show bilateral flattening of the head of the humerus and lipping of the glenoid margins. The intervertebral disc spaces are obliterated and the approximated surfaces of the vertebral bodies are sclerosed and thickened. Irregular islets of decalcification are shown in the femur *Hardman* has exhibited similar radiographs of this condition (see Figs 484 A and B) Further illustrations are to be found in the papers by *Puhr Uebermuth*, and *Sonderbergh*.

The characteristic changes of osteoarthritis are described in the regional sites *P B Magnuson* has pointed out that the picture of hypertrophic or degenerative arthritis as seen on the operating table in various stages of development is synonymous with the findings produced in animals by often repeated small traumata of an unstable or constantly traumatised joint.

LYMPHADENOMA

In some cases of so-called *Hodgkin's* disease, lymphadenomatous deposits develop in the bones. Such deposits produce radiographic appearances which are indistinguishable from metastatic carcinomatous deposits in bone.

The histological characters of the infiltrating cells may be very confusing, as in the case described by *Blount*

Radiographs of a girl aged 17 years showed deposits in the dorsal vertebral bodies. The condition was diagnosed and treated as *Pott's* disease for 15 weeks. Later irregular areas of rarefaction with peripheral sclerosis were seen in the upper third of the humerus. Some of the tissue was removed at operation and submitted to various authorities for an opinion.

Phemister considered that the tissue was that of a *Ewing's* tumour; *Codman* a hyper nephroma *Mallory* a malignant tumour; *Simmons* a *Ewing's* tumour; *Ewing* some form of myeloma. There was temporary improvement following X radiation, but the patient died 2 years after admission. Tissues removed at post-mortem showed histological features which were interpreted as lymphadenoma.

The distribution of the lesions in the two conditions, metastatic lymphadenoma and carcinoma, is very similar *i.e* the bodies of the vertebræ, the pelvis and upper ends of the femora and humeri isolated deposits may also be found in other bones. The affected vertebral bodies may show circumscribed areas of osteoporosis with collections of amorphous calcium, areas of increased density general cancellous destruction and collapse, or general increase in density as in Paget's disease (see Fig 410).

Pathological fractures may occur in the neck of the humerus or femur If the bone lesion is discovered before deformity occurs, consolidation of the bone can be brought about by X radiation.

Lockwood, Johnson, and *Varr* give the details of a case of Hodgkin's disease and publish radiographs of the bones of a boy aged 15 years In 1927 the boy developed bilateral shingles, but no bone changes could be detected in the radiographs of the lumbar spine Radiographs in 1928 and 1929 show central osteoporosis of the vertebral bodies with almost complete collapse of the first third and fourth lumbar bodies. The intervertebral discs appeared to remain intact The patient died in 1929 and at a post-mortem examination nodules of whitish tissue were found scattered throughout the viscera and bones which had the histological characters of lymphadenoma

tion of the abnormal bone is very similar in the two cases, a feature which has been noted in the author's cases *Dixon* expressed as his opinion that the abnormal bone is laid down in the areolar tissue rather than the musculature.

Other cases have been described and illustrated by *Lasker Laux, Magruder Cone Mackinnon Frejka Zielinski* and *Braithwaite*

Localised myositis ossificans is due to trauma and is most commonly seen on the outer surface of the femur and in front of the elbow It arises from ossification of a hæmatoma in that area (see pp. 111 and 218)

Bands of ossified tissue may be seen to unite the femur to the ilium, following trauma in that area.

The radiographs of the case operated on by *Naughton Dunn* (Figs 232 A and B) show that following the resection of the intervening bridges, the irregular ossified masses attached to the bones become absorbed.

Calcified Parasites. Echinococcus, Cysticercus Cellulosae, Trichina Spiralis, Dracunculus Medinensis Oncocerci Pentastomes and Sarcosporidia in the musculature undergo calcification with age

Echinococcal Cysts are larger than any of the other parasitic lesions. Calcification usually begins in the outer wall of the cyst as plaques irregularly disposed over a curved surface Ultimately the cyst shrinks and the calcified mass becomes dense and irregular in outline

The cysts of Cysticercus Cellulosae appear in the radiograph when the parasites are calcified. This may not occur for 10 years as multiple ovoid shadows 0·3 to 1 centimetre in length are scattered throughout the musculature having their long axes for the most part in the principal axis of the muscle fibres. Their presence may be associated with superficial nodes which can be felt under the skin (see Fig 189)

Calcification of the lens of the eye may simulate cysticercus cellulosae. The author recorded a case in which the eye had both lesions [89]

Trichina Spiralis is a very small worm which forms a cyst about the size of a grain of sand, and is therefore just discernible by the naked eye. These cysts are usually present in great numbers but owing to their small size they would be detected only on dental films if present in the muscles of mastication or perhaps on radiographs of the hands. They do not become completely calcified for several years.

Dracunculus Medinensis or guinea worm may be detected as a calcified worm-like body in the soft tissues of the calf and foot

Radiographs showing calcified guinea worms are published in *Connor's* paper

Oncocerci are worms which produce a rounded nodule rather larger than a pea within the musculature

Pentastomes form calcareous nodules about the size of peas They have been detected on radiographs of the upper lumbar area. The parasite is known to have become encysted in the liver and spleen.

Sarcosporidia are protozoa which produce spindle-shaped calcareous nodules in the musculature The size of these nodules shows considerable variation. They may be of microscopic size or the size of a haricot bean. The larger specimen resembles the calcified cysts of cysticercus cellulosae, as will be seen from the illustrations in a previous publication by the author [1]

Calcifying and ossifying hæmatomata are seen in close proximity to bones with or without fracture in limbs with disturbed or defective nerve supply as in infantile paralysis spina bifida injury or disease of the spinal cord or nerve trunks. Large hæmatomata occur in scurvy (see Figs 494 and 495)

Calcified Vessels and Aneurysms. Calcification of the pericardium and of the valves

The lower extremity of the femoral diaphysis may become wine-bottle shaped due to subperiosteal hæmorrhage. The skull may show a fine mottled osteoporosis somewhat resembling that of hyperparathyroidism. Similar osteoporosis may be seen in the pelvis. The long bones and ribs may exhibit lace-like accretions of periosteal new bone. The wrists and ankles may show marked osteoporosis of the carpus and tarsus with circumscribed areas of cancellous destruction in the subarticular bone.

Localised areas of cortical destruction may be seen near the diaphyseal extremities. In the adult these localised areas of cortical destruction usually associated with swelling of the surrounding soft tissues, may be mistaken for localised osteitis, and be treated as such. Such areas may involve so much of the shafts of the long bones that spontaneous fracture occurs. Because of such changes collapse of one or more vertebral bodies may occur. In 1 case reported by *Lyon* the patient had complained of pain in the back for a year but was not radiographed until 8 days before her death.

Interesting accounts have been reported by *Baty* and *Vogt*, *Lyon*, *J. J. Clark*.

CALCIFICATION AND OSSIFICATION OF THE SOFT TISSUES

Myositis Ossificans Progressiva. In this condition radiographs show irregular spikes or bands of bone in the soft tissues. They are particularly noticeable in the region of the ribs and scapulæ, the lumbar area and the pelvis. Smaller osseous spurs may be seen jutting out from the long bones of the extremities which usually show thinning of the compact cortex and absence of internal cancellous trabeculation. The little finger may be shortened and deflected by a shortening of the middle phalanx and obliquity of the articular surface of its head. The thumbs and big toes are shortened owing to defective ossification of the head of the metatarsal or metacarpal and the proximal phalanx. The latter feature helps to distinguish this type of myositis ossificans from the simple localised form which develops in the soft tissues following trauma (see Fig. 18).

The child affected with this dystrophy shows a progressive stiffening of its back and limbs. Marked scoliosis of the spine and deformities of the ribs follow fixation by these abnormal bands. Calcification of the tendon sheaths may be shown. Abnormal osseous strips were seen by the author in the muscles of the back in a child 2 years of age.

The appearances are shown in Fig. 879.

The radiographs of the case published by *Mather* show extreme deformity of the thorax.

Aisenberg has published radiographs of a child aged 6 years which show a collection of calcified nodules in the neighbourhood of the shoulder joint, irregular plaques in the flexors and extensors of the elbow joint, along the lateral thoracic wall, in the thigh and around the great trochanters.

The child appeared to be healthy until 3 years of age when she contracted malaria. 4 months after this, ossification of the musculature began.

Caser and *Jaubert de Beaujeu* report the details of similar findings in a boy aged 2 years. They state that at the age of 6 months tumours appeared in both sides of the neck which led to considerable impairment of the mobility of the neck. Three months later further nodules appeared in the occipital area. All these formations disappeared spontaneously within a period of 3 months, but the functional disturbances persisted.

The patient was heredosyphilitic, and the authors consider this to be the ætiological factor.

Two excellent complete skeletons showing the characteristic features of this condition are preserved in the Anatomical Department, Trinity College, Dublin. The distribu-

They may be associated with destructive erosion of the adjacent bones. As the result of such lesions the adjacent joint movements may be considerably limited and in severe cases contracture may occur These deposits are found more commonly in women. Though they are often not discovered until middle adult life, they have been found in young children

It was *Duplay* in 1870 who first drew attention to the deposits of calcium in the region of the humeral head. He called the condition **Periarthrite Scapulo-humerale** The calcium deposits have been found in the bursæ of the neighbourhood and in the tendon of the supraspinatus.

Under the name of **Peritendonitis Calcarea** *Sandstrom* refers to three forms, acute chronic, and latent The acute is associated with pain, local œdematous swelling tenderness, restricted mobility subfebrile temperature, often an increased sedimentation rate. Localised calcification can be seen on radiographs After X ray therapy it may completely disappear within 2–3 weeks. He advises 70–100r units every other day until symptoms disappear In the chronic form the symptoms are less significant. There may be flares with latent intervals

The condition occurs most frequently between the ages of 40–60 years The calcium may persist for months and may disappear without any form of treatment. He shows a series of radiographs illustrating the lesion before and after X radiation therapy

Moberg has described 5 cases of widespread subcutaneous calcification in the connective tissue of the leg in elderly females, 65–77 years of age. In none of the cases was there generalised calcinosis.

Localised deposits of calcium in the region of the ligamentum nuchæ, the so-called **Calcinosis Circumscripta Ligamenti Nuchæ.** Radiographs show single and multiple deposits in the soft tissue superficial to the spinous processes of the cervical and upper dorsal areas.

Calcinosis Universalis. This as its name suggests indicates a widespread and almost symmetrical distribution of calcium in the skin, subcutaneous tissues and fascial planes It may be discovered at birth as in the case reported by *Bloxham* and *Johnston* This infant showed superficial plaques of calcium and deposits in the neighbourhood of the joints and spine Diet aimed at correcting the defective calcium metabolism resulted in the absorption of much of the calcium, but even at 7 months deposits were still present in the ankle and knee-joint areas. At 11 months congenital cataract appeared in both eyes. *Swanson Forster* and *Lob* reported a case which was first discovered at the age of 5 weeks and by the age of 8 months all the deposits had completely and spontaneously disappeared (see also pp 17 and 18)

Radiographs show extensive deposits of calcium in the subcutaneous tissues and fascial planes sometimes associated with definite osteoporosis The deposits in one of the author's cases were widely distributed throughout the subcutaneous tissue but so fine that they almost escaped recognition. It was associated with changes in the skull resembling hyperparathyroidism and diminished urinary function.

The type with massive deposits is a much more serious one and the prognosis is unfavourable. Signs of acute localised inflammation, with œdema, may be followed by necrosis of the skin overlying the deposits leading to discharge of the calcium, to ulceration and permanent cicatricial deformities. The blood chemistry does not as a rule show any definite departure from the normal though some authorities have recorded higher calcium figures

Treatment There is no specific treatment *Craig* and *Lyall* gave a child of 5 years ½ drachm of Alkaline Sodium Phosphate 3 times a day for a week, then 1 drachm 4 times

is not often shown on the radiograph, but a number of radiographs showing the calcification have been published.

Calcified plaques in the walls of the aorta are a more frequent radiographic finding. Such plaques may be seen in the wall of the abdominal aorta, in the lateral radiograph of the lumbar spine situated about ½ inch in front of and parallel with the anterior surface of the bodies of the vertebræ. The outline of the vessels of the extremities is frequently seen in arteriosclerotic patients. The walls of all the arteries may be calcified at a relatively early age in cases of renal rickets type B. Calcification of the vessels of the choroid plexus, the internal carotid artery and in angioma may be shown on radiographs of the skull.

Calcification of the walls of aneurysms appear on the radiograph as circular rings of calcium, of sizes varying from the size of a pea in the carotid vessels to the huge aneurysmal sacs of the aortic arch. In addition to the carotid and aortic aneurysms, similar lesions have been detected by radiography in the renal and popliteal arteries (see Fig. 446).

Reference is made on p. 556 to a case of *Albers-Schönberg's* disease described by *Schulze* in which all the large vessels, the myocardium, the walls of the stomach and the kidney pelves were calcified.

Irregular Deposits of Calcium. Radiographs illustrating irregular deposits of calcium in the femur and os calcis are shown in Figs. 147 and 206. They denote aseptic infarcts or healed inflammatory foci.

Deposits of calcium are frequent in the region of the shoulder joint. Their presence is often associated with past injury. They may or may not be associated with pain. They may be within the subdeltoid or other bursa or the tendon of the supraspinatus near its insertion. In some cases the calcium is in a fluid suspension and may be withdrawn or washed out with a syringe (see also p. 108).

Collections of calcium in the myocardium, lungs, stomach, kidneys, ureters, gall bladder and biliary ducts, etc., are frequently observed in cases of hyperparathyroidism.

Any tissue which has been cut off from its blood supply, such as the interior of tumours, particularly myomata, may undergo calcification.

Calcinosis. Two forms are generally recognised, *i.e.*, Calcinosis Circumscripta and Calcinosis Universalis.

Calcinosis Circumscripta (see also Chondrodystrophia Calcificans Congenita, p. 17). This term is applied to localised deposits of calcium in particular sites, the commonest being the soft tissues over the terminal phalanges. These deposits are usually isolated and unassociated with any similar deposit in other parts of the body. They occur in association with minor vasomotor disturbances such as chilblains, and in the more serious lesions of thrombo-angiitis obliterans, Raynaud's disease, Scleroderma and Sclerodactylia. As in all other sites the deposits are not usually discovered without radiography. Radiographs show ill-defined dense deposits of calcium in the soft tissues chiefly over the palmar aspect of the terminal phalanx, but in some cases over the middle phalanx as well. The terminal cancellous tuft of the end phalanx may be absorbed as in Fig. 48 C and there may be some degree of osteoporosis.

In other patients calcium deposits may be found in the neighbourhood of joints and bursæ, *e.g.*, over the head of the humerus, coracoid and acromion, the lateral humeral condyle, the olecranon, the ulna styloid, the anterior superior iliac spine, the greater and lesser femoral trochanters, the patella, the malleoli, the great toe and the os calcis. *Most of these sites are subjected to trauma* and some authorities regard this as the causal factor. They may be quite symptomless and be discovered by radiography for other purposes. They attract attention clinically when the overlying tissues show the signs of inflammation. This may be followed by ulceration and discharge of the calcium.

CHAPTER XXVI

BONE TUMOURS

General. No greater responsibility is placed upon the radiologist than that of the interpretation of the radiographs of a bone tumour as to whether it is simple or malignant. It has been abundantly shown that cure of malignant disease of the bone by any method of treatment is very rare, and that, like malignant disease in any other tissue, cure as yet appears to be dependent upon the early recognition of the localised metaplasia and its prompt eradication.

The development of a malignant tumour is insidious, and in its early stages is not accompanied by any characteristic sign, nor any prominent symptom. Patients affected with tumours of bone seek medical advice because they (1) have noticed an unusual localised swelling, tenderness or pulsation, and/or (2) have experienced localised discomfort, pain or disability, and/or (3) have sustained a fracture. No age is immune from these lesions—they may be recognised at birth or be the deciding factor of death in the aged. They occur in patients of all grades of society, in patients who appear to be in the pink of condition as well as in those who are emaciated or cachectic. In other words there is no general sign which is characteristic. Nevertheless every care must be taken in getting the history of the lesion and in making the clinical investigation before calling in the aid of the ancillary services.

Examination of the Patient. ***The Age of the Patient.*** Though certain types of tumour are to be seen at all ages of life, each age-period has certain tumours which predominate, notably the neuroblastoma and those which are associated with the deficiency diseases of infancy; the dystrophies, inflammatory lesions and sarcoma of adolescence; the inflammatory lesions, chondromata, osteoclastoma, to cysts and sarcomata of early adult life, the carcinomata and myelomata of later life.

The Temperature. Elevation of the temperature may or may not be present with inflammatory lesions, may be high in certain malignant tumours, but is unaffected with simple neoplasms. With certain tumours, such as those due to inflammatory processes or endothelial myeloma (Ewing) the temperature may show bouts of elevation with long periods of normality.

The Pulse. Though affected in inflammatory conditions and during the bouts which characterise the conditions which influence the temperature, it shows no characteristic feature with neoplasms.

The Respiration. It is remarkable how extensive secondary tumour dissemination throughout the lungs can be without any obvious change in the respiration—multiple secondaries from sarcomata or teratomata of the size of golf balls can be present and yet give no clinical indication, for as a rule they do not produce any reaction in the surrounding lung tissue which by hypertrophy compensates for the area obstructed. In certain cases dyspnoea becomes a distressing feature.

Whenever the malignancy of bone tumours is suspected complete examination of the chest (including radiography) must be made. This will be referred to in a subsequent chapter on radiographic examination.

An essential part of the routine clinical investigation is an examination of the number and characters of the blood cells (in certain cases the percentage of its chemical constituents, calcium and phosphorus); its Wassermann reaction.

The urine examination must include a search for Bence Jones proteose.

a day and at the end of 6 weeks radiographs showed that most of the calcium had disappeared.

Sandstrom advises X radiation therapy (see p 675). *Hein* found good response to ultra violet radiation.

Further contributions to the subject have been made by *Gould* and *Balford*, *Rothstein* and *Welt* *W D W Brooks* and *Steinitz*.

Under the title of **Lipo-calcino-granulomatosis** *Sommer* and *Trees* have described a special form of calcinosis universalis The lesions were progressive and symmetrical, they involved the synovial cavities and were associated with degeneration of the fatty tissue and dystrophic calcification In 1 case seen by the author large calcium deposits were shown around all the large joints and these were associated with some erosion of the bony extremities. Isolated lesions with radiographic appearances of this nature occur in some cases of tuberculous arthritis (see Fig 206).

In the condition described as **Progressive Ossifying Poliomyelitis** by *Münchmayer* the clinical and radiographic features may simulate calcinosis universalis

The radiographs of cases exhibiting **Werner's syndrome** show calcification in the vessels and soft tissues associated with some osteoporosis of the bones. The ætiology of the condition is obscure. Cases show a generalised underdevelopment of all the *endocrine glands, hypogenitalism, eunuchism, and premature senescence.* There is extensive and widespread arteriosclerosis of the Mönckeberg type and scleroderma; premature greying of the hair and bilateral cataracts

S T Herstone and *J Bower* give an account of 3 cases, 2 of them being brothers They died at the same age period, *i.e.*, 41 42, and 44 but from different causes, heart disease carcinoma and fibrosarcoma

Further Investigation. From the recital of the preceding it will be apparent that the clinical features in bone tumours are extremely variable and of themselves do not permit of identification of their nature so we must turn elsewhere for supporting evidence Notwithstanding the truth of Bloodgood s statement, Less and less to-day are the clinical features of benign and malignant tumours of bone or of diseases of bone helpful in the diagnosis, but they should never be neglected. In former years, when malignant disease could be recognised clinically there were no cures " the clinical investigation must be routine and thorough. Facts elicited in this way may be the essential ones on which the accurate diagnosis depends.

Though as a general rule it is wise to fit the whole clinical and scientific picture of the lesion or lesions into one category be it congenital maldevelopment, familial or deficiency dystrophy disorder or disease of the skeletal or nervous tissues, viscera, endocrine glands or blood, reaction to trauma or inflammation from any cause, or neoplasm, it must be realised that the presence of a lesion characteristic of any one of these does not confer immunity against the development of a lesion or lesions in other categories : several may run concurrently Occasionally the composite picture obtained from the investigations is obscured because of a mixture For instance, because a patient has a dystrophy there is no reason why he should not develop syphilis or rickets, and there is no reason why a patient with syphilis should not develop sarcoma, and *vice versâ*.

Unfortunately because this interrelationship has occurred and not been recognised, cases in one category have been described as having not only the well-established clinical, biochemical, histological and radiographic features, but the features due to other influences. Lesions bearing but a very superficial resemblance to well-known conditions have been described, illustrated and published, and these, again have been quoted or copied into later publications as the evidence that certain unusual features characterise one or other category

Though in former days surgical exploration or biopsy was adopted, because such measures could readily be done, to-day with the availability of radiographic equipment in the smallest of hospitals, following the clinical investigation, this should be the first court of reference

Radiography *Radiographic Investigation.* John Hunter made the comment, It is surprising to see what little curiosity people have to observe the operations of Nature, and how very curious they are about the operations of Art. If that was true in his day how true it is to-day though we have in radiography a method of observing the inner operations of Nature without giving the patient any mental or physical pain. Only too often the radiograph is used to obtain a spot diagnosis which is precipitately followed by operative measures, instead of using it to watch the development, regression or progression of the lesion before and during the exhibition of medicinal agents. It may be urged that the all important factor in the cure of malignancy in bone is early amputation, and therefore the less time between radiography and surgery the better There are many surgeons who, in their desire to obtain further evidence of the nature of the tumour would not hesitate to cut down and take a piece out though this carries with it the risk of an anæsthetic and other dangers which are mentioned elsewhere But there are few surgeons who would care to amputate a limb for a symptomless lesion which had no clinical signs and as yet indistinguishable radiographic signs on the other hand we see patients for the first time with metastases, though only a relatively small localised primary is present. We must always bear in mind that the lesion of which the patient complains may be a secondary metastasis—particularly is this so in patients who have reached middle or late adult life (see Fig 407)

The Condition of the Patient. In simple neoplasm, and at the early stage of certain malignant tumours, the patient, except for some localised sign, may appear to be in very good health. It must not, however be forgotten that simple tumours can occur in patients who are seriously debilitated by some other factor Some patients with sarcomata or secondary carcinomata of bone show marked pallor others present a parchment like skin or show the drawn features of long-endured agony or the languid aspect and emaciated body of the dying **The radiologist must see the patient and lesion.**

The Lesion. An obvious tumour may or may not be apparent. The skin over it may be of normal colour or unchanged it may appear to be tightly stretched over an expanding lesion and be glossy with little colour or it may present a dull cyanotic appearance The veins over the lesion may be increased and dilated they may be more apparent by infra red photography In some cases unusual pulsation can be felt. The tumour may appear to be of stony hardness and associated with the underlying bone it is rare to detect true fluctuation in association with a neoplasm of bone it may occur as the result of secondary changes. A sensation of crackling may be elicited by pressure There may be no tenderness, but in other cases it may be so exquisite that the patient is alarmed by the approach of the examining hand : this may occur though no definite tumour can be felt. The gravity of the pain shows considerable variation. It may amount to little more than discomfort ; or may be so severe that only morphia will give relief It may be sharp or stabbing in nature, or of a continuous dull, boring character It may come on in bouts lasting but a few minutes, hours, or even weeks ; the intervals between the bouts may be a few hours or months. It is unusual to have starting pains with the relaxation of sleep. Movement of the adjacent joint may be carried out without pain, though it may be restricted in extent. **The clinical signs may be prominent though the radiology is still normal.**

There may be more than one site, with or without associated clinical signs and symptoms.

If a fracture has occurred this may have been spontaneous during normal function at a site, which may or may not have been associated with any of the above clinical signs or symptoms—this is a most suggestive sign of malignant neoplasm. When the fracture has occurred as the result of severe trauma the possibility of underlying neoplasm may be overlooked, particularly if the patient denies all evidence of previous signs, and the question of compensation may not be without its influence in this respect. The time of the injury must be carefully recorded, for it may be most helpful in the interpretation of radiographic appearances (see Fig 498)

The History of the Lesion. The attention of the patient may have been attracted to the lesion within a few hours of the medical examination, particularly if associated with fracture It must, however be realised that trauma, sometimes trivial in nature to a lesion of long duration, may have been the cause for the patient noticing it the trauma may be thought to have produced it. But in some cases the patient has been aware of discomfort, pain or even a tumour for weeks or even years before, and advice is sought because of aggravation or change in the signs. The rapidity of the growth of the lesion varies considerably in some a notable change occurs within a few weeks, in others many months may pass without any perceptible extension.

Previous History of the Patient. The previous medical and surgical history of the patient is of great importance It may reveal the site of an old injury a primary tumour or the nature of earlier tumours, hæmophilia, leukæmia, scurvy the osseous or chondrous dystrophies The history of sepsis, tuberculosis or syphilis may throw very considerable light on the nature of the tumour The family history may indicate the possible nature of lesions which had previously been unsuspected.

to examine the lesion on several occasions with a fair interval between each depending upon the rapidity of growth of the tumour

In those cases having radiographic appearances which are known to be typical of a specific lesion the nature of the lesion should be stated It may be that the clinical and histological data are at variance with the radiological This should not cause the radiologist to waver in urging his positive finding for this is the most important feature of the case For the same reason if tubercle bacilli were found in the lesion this evidence would rank before any doubtful clinical or radiological data.

Unfortunately there are many cases in which the radiographic appearances are indefinite This must be stated as clearly but in addition an indication should be included in his report of the pathological changes which could produce such radiographic appearances in a patient whose clinical history signs and symptoms were consistent with such pathology There are examples of malignant tumours the natures of which are indicated during careful clinical examinations only and in which the radiological findings may be little or indefinite. In others as we have seen, the microscopic picture is the essential factor in elucidating the problem ; both the clinical and the radiological findings conflicting or agreeing to obscure the diagnosis There are a few which remain as problems in spite of the most exhaustive clinical, histological and radiological investigations There is often a long negative radiographic latent period.

Each of the trio may play an essential part We are concerned with the early diagnosis of the tumour for on this may depend the life of the patient

With the demand for earlier and earlier diagnosis the difficulty of interpretation of radiographic appearances will increase Once the quest for early signs is begun innumerable indefinite features will loom up each day and only by constant watch and numerous re-examinations will the significance of these changes be learnt. We shall find that though certain lesions present identical characters in their beginnings, the ultimate development is widely different. Just when the specific characters of the lesions appear which will enable us to differentiate we must learn to detect if we are to give the best service Such a service demands the best radiological technique to show the intimate detail of the bony structure Radiographs of the opposite limb may be invaluable for comparison and these should be scrutinised for signs of any defect or abnormality Stereoscopic radiographs will sometimes give emphasis to small areas showing cancellous change which may escape attention in the plain radiograph.

Further evidence of the nature of a bone tumour may be obtained in certain cases by examination of the lung fields the lumbar spine, and the pelvis. These may show evidence of metastases or bone changes of a specific character

It is most important that a complete radiographic record be made before any therapeutic measures are instituted This applies in particular to X radiation and radium therapy for such radiation may completely mask the nature of the bone tumour It can cause the most pernicious lesion to take on the radiological and even the histological characteristics of simplicity or even normality and by so doing rob the patient of the possibility of early diagnosis and treatment.

Notwithstanding all the possible fallacies following a thorough clinical examination, radiology must be the first court of appeal in all lesions of bone for it is capable, in the majority of instances of indicating to the experienced observer the pathology long before the clinical appearances can suggest it and before surgical measures for biopsy or treatment are justifiable

James Ewing says "The whole clinical and radiological picture of the case of bone sarcoma usually furnishes a better conception of the diagnostic and therapeutic

To-day it is a routine procedure to radiograph the affected part as the first step in the investigation. (It would be advisable to radiograph the chest at the same time.) Sometimes this is done before and sometimes without any clinical investigation worthy of the name—an important omission which may have serious consequences, due to misinterpretation of the radiograph. In radiographs we have a method which permits ready diagnosis of a large proportion of simple and malignant tumours without inflicting on the patient any additional discomfort, pain, or complications. Unfortunately the nature of all bone tumours cannot be detected by the first radiographic examination, and it is more unfortunate still that it is generally in just these cases that the histological features are likely to be indefinite and misleading

Further the literature contains not a few instances in which the clinician has been led astray by erroneous radiological reports It is the duty of the radiologist to see that these are reduced to the minimum.

Since the acknowledgment that the chance of cure of malignant disease is dependent upon its early recognition there has been a tendency to seek the radiologist's opinion at an earlier stage, and with this a greater responsibility and a greater difficulty are thrust upon the radiologist. The knowledge needed for the recognition of a well-developed lesion having characteristic radiographic and clinical features can be readily acquired but since many simple and malignant conditions present in their early stages radiographic appearances which are very similar—so similar in fact, that one description may appear to portray all—considerable experience is essential for their early identification. Bone tumours, fortunately are relatively uncommon in any one practice but, unfortunately as a result of this infrequency the radiologist, unless he has made diseases of bones and joints a special study and for this purpose has established consulting contact with his colleagues, sees but a small number of such cases It follows therefore, that the average clinician who sees but a small proportion of the cases referred to the radiologist in any one area has a correspondingly reduced experience and must consequently appreciate the necessity for seeking and acting on the advice of such a consulting body comprising clinician, radiologist and perhaps pathologist, as the American Register of Bone Sarcoma instead of depending on his own clinical judgment or radiographic interpretation. When advantage is taken of such consultative facilities, all available evidence should be submitted.

The radiologist has his responsibilities and he must not shelter under what has perhaps in the past been the domination of the clinician In his report he must not merely draw attention to irregularities of outline. That could be done as well by the radiographer or the clinician but he must, from his special knowledge, give his opinion of the nature of the pathological changes underlying the irregularities and so guide the clinician as to subsequent treatment. Often he can do this only if he has the clinical, and in some cases, the histological knowledge.

Ewing expresses it in another way when he states "An essential safeguard for the pathologist in the diagnosis of bone tumours is the possession of full clinical and roentgenologic data. No breadth of experience can dispense with these aids in dealing with the variable structure of bone tumours.

To give to the clinician merely a description of radiographic appearances, no matter how perfect such a description may be is to shirk the responsibility and put the interpretation on the clinician, whose knowledge of radiographic appearances can only be very limited and in this manner the radiologist loses the opportunity of rendering to the patient those services he sought, and for which, in some cases, he has paid dearly In a number of cases we can get a characteristic radiographic appearance which will enable us to give a diagnosis, and this number will be increased if we have the chance

The signs of the lesion may have been overlooked it may yet be so small that it has not reached macroscopic dimensions, or may not yet have produced sufficient contrast density or transparency with the normal tissues to be recognisable.

It must be realised as I have shown that there is a latent period not only between the inception of the lesion and the appearances of radiographic signs, but also between the onset of clinical signs and the appearances of radiographic evidence. The clinical signs in acute osteomyelitis are usually prominent for a week to 10 days before the slightest change can be detected in the bone by radiography—with lesser degrees of virulence and prominence of clinical signs the latent period is usually correspondingly increased—the more diffuse the invasion the less readily will gradual changes be detected particularly when these are generalised and comparison with an opposite normal structure is denied. The detection of evidence of infiltration of bones by secondary carcinoma calls for the most careful scrutiny—the latent radiographic period in these lesions may extend into months The radiography must be repeated according to the rapidity of change or persistence in severity of the clinical signs. Lesions of the sacrum, ribs and dorsal spine are often masked by the contrast transparencies and densities due to gas or air in adjacent structures, and care must be taken to exclude these. Changes in the radiographic appearances of the tissues associated with tumour formation may be due to congenital abnormalities, dystrophies of the skeleton, deficiency diseases and diseases of the hæmatopoietic system, trauma, inflammation or neoplasm. Many of these produce characteristic radiographic appearances which, when established, permit of ready diagnosis They have been described and illustrated in earlier chapters.

Trauma. Malignant metaplasia (*i.e.*, the development of sarcoma) as a result of recent trauma to healthy bone is so rare that if in the opinion of an experienced observer the radiographic appearances could be due to the trauma, it should not be considered until all the possibilities of a benign lesion have been excluded. In about 50 per cent of cases the patient will give a history of trauma but as a general rule it will be found from the radiography that the lesion was present long before the injury—the latter merely drew the attention to a previous symptomless lesion In my experience which embraces radiological investigations of injuries received during and between the two world wars I have seen but two cases of genuine sarcoma arising at the site of a well established trauma—in both of these there had been fracture at the sites more than 10 years previously In these cases it was the clinical features only which indicated that malignant metaplasia had occurred—the radiographs showed what appeared to be merely the effects of the old injuries. I would again stress the importance of radiographic investigation as soon as possible after trauma—such radiographs may be invaluable in determining the relation of the trauma to any lesion which subsequently develops. Unsuspected fractures the so-called March fractures receive the trauma of function until discovered, consequently unusual callus may develop at the site creating appearances which have been mistaken for sarcoma and led to amputation. It may not be easy to say this if radiology is postponed for some weeks or months The writer has seen many cases where the evidence of a pre-existing lesion existed, but he has seen a number where the bone at the site soon after the injury showed no departure from the normal bone adjacent to it but radiographs some weeks or months after have shown the typical appearances of neoplasm. It is impossible to say that an early metastasis which was still invisible was not developing at the time of the injury but we have seen inflammatory lesions pyogenic tuberculous and syphilitic, develop at the site of trauma, and it is reasonable to believe that tumour cells circulating in the blood could also settle out in the injured tissue (see Fig 408)

The author has pointed out that the patient may not remember receiving the trauma ;

problem than can be obtained from a biopsy Often the rate of growth, the extent of the disease, and the radiological details indicate the general nature and grade of malignancy of the process better than does the histological structure of the tumour but this is not always the case. Few surgeons realise the limitation in the histological diagnosis of bone tumours and the conditions which simulate or accompany them."

If the radiographic evidence suggests that the lesion causing disability or symptoms, or likely to result in fracture is simple and operable measures should be undertaken which will eradicate the lesion, for even such lesions as simple and multilocular cysts exostoses and chondromata have been seen ultimately to undergo malignant metaplasia. Any bone removed should be submitted for histological examination. If this confirms the simplicity of the tumour the surgeon will be satisfied with the nature of the operation. If the histology suggests malignancy though the radiology indicates simplicity the case can be periodically examined for supporting evidence and any further operative measures determined by this. Immediate amputation in such a case following a report of malignant histology is unlikely to increase the patient's chances and may be unnecessary The histories of patients observed with typical clinical and radiographic evidence of malignant lesions in whom amputation followed on a biopsy suggest that the chances of cure are small. Therefore, *in doubtful cases there is justification for further observation.*

From a careful examination of a large number of radiographs of cases which have been submitted for my opinion, I have made the following classification of the early radiographic signs of malignancy In some of the cases the changes are already very extensive, but they represent the appearances shown at the first radiographic examination; presumably the clinical features previously had not been considered sufficient to warrant further investigation.

Radiographs of the highest quality should be insisted upon. Except in a few cases the patient can be placed in all the positions for standard radiography and this will best indicate the site of the lesion. The suspicious focus should occupy the middle of the film, and the latter should be large enough to include a wide periphery If the lesion is in the neighbourhood of a joint, the joint on the opposite side should be included and the central ray projected over the mid line of a symmetrically arranged body and limbs. The quality of the radiograph should be such as shows soft tissue outlines as well as the intricate cancellous detail and contour of the bones. If the resultant radiograph is not entirely satisfactory or shows any defect or departure from the normal at a site which is not within the central area of the radiograph, further radiography to secure this must be made: this is particularly important for comparative examination at a later date.

In the examination of the radiographs the general conformation and outlines of all bony structures must first be noted any degree of osteoporosis or of increased density general or localised the thickness and regularity of the compact tissue the clarity and entirety of the cancellous pattern the comparative dimensions of the opposite joint spaces—any changes or increase in the soft tissue shadows.

The early lesion may show little departure from the normal, and as success in treatment is largely dependent upon the recognition of this, the scrutiny of the detail must be particular notably at the site suspected at the clinical examination and in the juxta-epiphyseal areas which are the more common sites of pathological changes. If the radiograph reveals no evidence of pathology and the clinical signs are insufficient to call for immediate treatment the part should be immobilised and a further radiographic examination should be made after a period depending on the clinical condition of the patient in the first instance, after the passing of a week. Because the report on the radiographic examination is negative we must not conclude that the part is normal metastases have a long negative radiographic latent period.

extensive syphilitic lesions of bone may return to normality after efficient medication. Many limbs have been sacrificed unnecessarily because its activities have been mistaken, even by the experienced for those of malignant disease Even age does not need to be considered in syphilis. *Geschickter* and *Copeland* record a gumma in the fibula of a child



FIG. 485. Radiographic signs of malignancy in bone tumours.

aged 7 years, following injury It was diagnosed as a possible endothelioma—the bone was partially resected and found to be a gumma. It must not be forgotten that a patient with a sarcoma may have a positive Wassermann, but, distinct from sarcoma, the syphilitic lesion resolves readily and often completely when the patient is put on anti syphilitic medication (see history of case on p 718)

Like syphilis, malignant metaplasia may occur in association with any of the

injuries sustained during the excitements of pleasure passion, or danger may not be remembered The discovery of bruises or hæmatomata without any remembrance of the injury causing them is common.

B J Toth [13] has published an interesting account of a case in which a tumour developed at the site of a fracture through apparently normal bone.

The author radiographed a patient the day after the latter had been knocked down by a motor car At the time of the radiographic examination the patient had a severe contused wound of the buttock, but no bony changes could be detected on the radiograph Six months after this, the patient developed a pulsating tumour at the site of the contused wound, which was thought to be an aneurysm of the gluteal artery due to the trauma. When death occurred a few months after this, a secondary hypernephroma of the bone was found at the site of the tumour

Willan has published the radiographs of a patient who died from metastases of sarcoma 1 year and 11 months after an injury to the neck of the femur at which site a spontaneous fracture occurred 8 months after the accident.

Failure to appreciate all the above features has been responsible for unnecessary and damaging surgical explorations which with erroneous interpretation of malignant disease from the histological material so procured, has resulted in equally unnecessary mutilation of the patient or the risk of such. *S L. Baker* had given an illustrated account of 2 such cases. In spite of recent trauma and radiographic evidence that it had produced a fracture in both cases biopsies were performed at 5 and 8 weeks respectively At these large lumps of tissue, some measuring 4×2×1 cm. were cut out and what he describes as the not unjustifiable diagnosis of chondro-sarcoma was made from them. Fortunately the disarticulation at the hip joint considered was prevented by the poor condition of the first patient but the resolution in this case did not prevent a biopsy being undertaken in the second Neither did the radiographic evidence which he supplies of great extension of the hæmatoma due to the surgical exploration in the first case prevent an even more extensive damage in the second.

Before we can attribute a sarcoma to a known trauma we must be satisfied that the trauma was applied—this may have produced evidence such as a hæmatoma, contusion, laceration or fracture at a site which was previously without any sign or symptom that the clinical evidence of injury has been continuous with the development of the tumour that the radiographic evidence is of an apparently healthy bone at the site of the injury which subsequently developed the positive signs of malignant disease—this necessitates radiographs immediately after the injury and during the course of development of the lesion

The healing response of certain tumours to X radiation should be given a trial

Special attention should be devoted to the possibility of syphilis. Every investigation into the cause of any bone tumour or suspected case of malignant disease of bone which does not include a search for evidence of syphilis must be regarded as incomplete and the investigator as negligent. The spirochæte can produce lesions which are almost indistinguishable from many so-called typical lesions of other origin. The spirochæte is twisted in form and nature and can at any time twist the unwary It is found where it is least expected, in the suckling the meek and lowly as well as the high and mighty: it is one of nature's more formidable secret weapons

The appearances of lesions produced by the spirochæte may deceive the surgeon even at an exploratory operation, and there have been cases in which the histological appearances have deceived the pathologist but the time for the diagnosis of syphilis is not after exploration or amputation For the tragedies associated with, and consequent upon, the latter appear intensified to those who realise that even some of the most

primitive with irregularly formed and disposed osteoblasts, fibroblasts and osteoid tissue to the more mature fibrous chondrous or osseous tissue This tissue may be regarded as benign as in the cases I have published. They occur most frequently in the opposing ends of the diaphyses of the tibia and femur but they are occasionally seen in other bones. Such lesions should not be confused with the so-called osteoid osteoma, which I regard as a localised chronic abscess of the Brodie type.

Geschickter and *Copeland* claim the very high figure of 25 per cent. of cures with early amputation. Though there was early recognition and prompt amputation without any surgical damage to the lesion in the third case of the series which I published, pulmonary metastases developed within the year and death occurred soon after These lesions do not respond favourably to X radiation. Some metastases from carcinoma of the prostate show as rounded areas of increased density before they coalesce to produce a general increase in the density of the affected bone.

(*) *Needle-like spicules radiating in palisade fashion into the soft tissues* at right angles to the superficial surface of the cortex of the bone This is another highly suspicious sign, particularly when the spicules are fine straight and needle-like in shape As the tumour is watched it may be seen that as the spicular growth becomes absorbed at the primary focus it spreads along the shaft to its extremities. Such periosteal spicular growth may be associated with an increased density of the affected bone—which may be in marked contrast to the apparently unaffected adjacent epiphyses (see Fig 188) In some cases of secondary carcinomatous metastases, particularly from the prostate, the periphery of the cortex of the affected bone may appear to be woolly but on close examination of the radiograph taken with a fine focal spot it will be seen that there are firm closely packed spicules, ¼ to ½ inch in length, forming a plush like pile. Localised carcinomatous metastases may show an apparent destruction of the cortex with spicules radiating out from the sub-surface of the affected segments but as with most secondary carcinoma, in contrast with sarcoma, there is usually little soft tissue swelling In *Ewing's* sarcoma the bone may have shown initially a segment of expanded bone with a thickened and denser cortex which has a regular periphery but an irregular coarse cancellous trabeculation within after injury to the bone accidental or surgical, fine radiating spicular growth may be seen at the site.

Some localised syphilitic bony lesions, as well as the bone beneath an indolent ulcer such as a varicose ulcer may show what has been described as spicular growth, but this is coarser and quite different in appearance to the radiating spicular growth of sarcoma—it is more a response to inflammation of the periosteum.

(3) *Periosteal accretions over or cuffs on either side of the primary focus* Periosteal laminated accretions in themselves are not the sure sign of malignancy which is so often taught. Multiple periosteal accretions which run parallel with the periphery of the cortex associated with more or less complete obliteration of the normal cancellous pattern within are seen in *Ewing's* sarcoma (see Fig 228) but when seen syphilis must first be excluded for localised chronic inflammatory lesions particularly syphilitic sometimes have *appearances which are indistinguishable (see Fig 117 A). When the* periosteal accretions are broken down in the middle so that they form a cuff on either side of the primary focus with its greatest dimension towards the lesion and gradually diminishing in calibre away from the lesion, excluding syphilis the appearances are more likely to be those of sarcoma particularly if there is in the soft tissue tumour over the neighbourhood of the primary focus ill-defined wisps or clouds of calcium deposit When the thickened cortex shows the appearance suggesting localised clear-cut paring down to the dimensions of the normal cortex this is very suspicious of malignancy

In *Geschickter* and *Copeland's* book it is stated that periosteal bone formation is

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The appearances of lesions produced by the spirochæte may deceive the surgeon even at an exploratory operation and there have been cases in which the histological appearances have deceived the pathologist: but the time for the diagnosis of syphilis is not after exploration or amputation For the tragedies associated with, and consequent upon the latter appear intensified to those who realise that even some of the most

(5) *Localised expansion of bone which is denser than the adjacent normal bone* More commonly in infants and young adolescents a bone tumour will be found which is characterised by the radiographic appearance of a localised regular expansion of bone associated with an increased density a thickened cortex and obliteration of its cancellous interior though the medullary cavity may appear to be widened or narrowed and somewhat mottled in appearance The periosteal periphery may be quite regular and show no sign of spicules or localised destruction It appears to progress very slowly if it is undisturbed, but if injured by trauma, accidental or surgical (as for biopsy), a crop of palisade periosteal spicules may develop at the site In some cases spontaneous fracture occurs through the thickened denser bone and this is followed by the development of spicules and considerable decalcification the bone may now appear to be undergoing dissolution, the calcium is dissolved from the trabeculæ and the bone may present a lattice-like appearance ultimately these trabeculæ disappear Secondary deposits of this nature may develop in other bones in the course of a few months to 2 to 3 years Multiple secondaries may also occur in the lungs.

The histological features are usually those of a *Ewing* sarcoma. Any bone can be involved, but the upper end of the femur and the shafts of the long tubular bones are the most common.

(6) *Localised osteolysis of bone* This may be either cortical or endosteal. The cortical lesion is usually insignificant compared with the large soft tissue tumour This type of lesion is more commonly found at the lower end of the femur and the upper end of the tibia. From one aspect the bone appears to be gradually dissolved away often without any sign of calcium deposit in the soft tissue or reaction in the soft tissue or the adjacent bone, but in some cases the bony periphery of the tumour shows some reaction which is indicated by an ill-defined increase in density Gradually the tumour destroys the bone, but it is not until it has passed through a large segment of the bone that the periosteum of the other side registers any reaction—eventually it may show a line of parallel accretions of new bone before fracture or complete dissolution of the segment occurs. The periosteum of the adjacent segment of bone may show a similar reaction. In the rapidly growing tumour no sign of reaction is seen—only a progressive dissolution and decalcification. In some cases the tumours arise endosteally The involved segment of bone shows localised irregular cancellous destruction which may be interpreted as a bone cyst but on closer examination it will be seen that the trabeculæ are eroded at its periphery in an irregular manner there is no clearly defined margin and no reaction either in the adjacent bone or the overlying cortex or periosteum. Fracture of the bone may be the first indication, for previously no tumour could be felt. Following fracture, more rapid dissolution of the involved area occurs and a tumour becomes apparent. These tumours often metastasise early Secondaries may be discovered in the lungs at the first examination, though the primary tumour at that time is not large and has not attracted the patient's attention for more than three or four weeks. Such early secondaries have been seen in young persons under 20 years of age, but one must consider in such patients the possibility of the condition being due to a less fatal malady such as lipoid-granuloma. I have recorded disintegration of bone with multiple rounded lesions in the lungs resembling secondary sarcomata which entirely cleared and the emaciated patient completely recovered normal health (see Fig. 483 A and B). Radiographs of the skull showing the osteolytic areas described by *Schüller* may be very helpful in assessing Because of the complete destruction of a localised section of bone (and as it expands it erodes all bone it comes into contact with, as is particularly well shown when it affects the dorsal spine and ribs) and the large

lesions of the other categories we have considered, *i.e.*, congenital defects, dystrophies deficiency diseases, inflammation, simple tumours. Its possibility at the site of old trauma or an old subperiosteal hæmatoma has been illustrated

The Radiographic Signs of Malignancy in Bone Tumours. These signs see Figs 485 and 486 consist of —

(1) Localised ill-defined irregular area of increased density in a bone

(2) Palisade needle like spicules at right angles to the periosteal border of the bone.

(3) Periosteal accretions of new bone or cuffs on either side of the primary lesion.

(4) Periosteal irregular fibre-like spicules radiating from a localised area of damaged cortex, usually bounded by a periosteal reaction cuff at both ends

(5) Localised expansion of bone which is denser than the adjacent normal bone.

(6) Localised osteolysis of bone either cortical or endosteal.

(7) Localised irregular disintegration of a previous bony lesion.

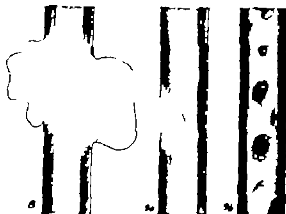


FIG 486. Metastases of carcinoma.

(8) Localised irregular cyst like extension and expansions of bone.

(9) Metastases in other bones or the lungs.

(10) Large expanding soft tissue tumour associated with normal underlying bone.

(1) If there is one sign which I regard as more highly suspicious of malignancy in itself than any other it is *an ill-defined and irregular localised area of increased density of a bone diaphysis or epiphysis* which has previously not been the site of any definite inflammatory change. The appearances suggest that in this localised area the interstices of the cancellous tissue have been packed with calcium. The margin of the reactive area on the medullary aspect of the tumour is ill-defined suggesting that the tissue is reacting as the malignant cells gradually infiltrate it—indeed, this is the histological picture The cortex of the segment involved may appear to be somewhat thicker and irregular but no spicules may be seen radiating into the soft tissues (see Fig 193). As the soft tissue tumour grows ill-defined calcium deposits may be seen within it resembling wisps of cotton wool. Serial radiographs will show a progressive spread of this dense reaction in the bone and further irregularity and thickening of the cortex and denser wisp-like strands of calcified tissue in the larger soft tissue tumour After some months central destruction of the dense bone may occur followed by its decalcification The metaphysis may be crossed. Such lesions have been called sclerosing sarcoma of bone. Histologically they show features resembling all forms of connective tissue from the most

may be seen in bony extensions or metastases from epithelioma and in xanthomatosis (see Fig 407)

(c) A combination of (a) and (b) occur more frequently in carcinoma of the breast;

(d) Multiple small well-defined round areas of cancellous destruction The medullary cavity of tubular bones may be expanded by scalloping of the inner cortical wall by the multiple rounded tumours. In myelomatosis such lesions may be seen in all elements of the bony skeleton, but they are particularly evident in the ribs, skull and pelvis

(e) Localised areas of erosion of the cortex with irregular density of the subjacent bone and spicules radiating from the lesion into the soft tissues Such foci may arise from carcinoma of the breast or prostate

(f) Diffuse decalcification of a bone or of much of the skeleton—this type is most frequently seen in neuroblastomata in infants and young adolescents, in whom it will be seen that while the diaphyses are extensively involved the epiphyses may appear to be relatively spared

Metastases in the bones often give rise to considerable discomfort or pain long before there are radiographic signs whereas metastases in the lungs may be so large and extensive as to leave little lung tissue yet give no indication of their presence until the dyspnoea near the end.

The period which elapses between the discovery of the primary lesion and the appearance of metastases shows considerable variation. In some cases of carcinoma a single metastasis in the bone may give rise to symptoms and be recognised months before the primary has been detected or even suspected In one case where I had reported widespread carcinomatosis of the skeleton the primary in the breast was not discovered until the post-mortem. In other cases metastases may not develop for 20 or more years after amputation of a structure containing the primary carcinoma.

Metastases from sarcomata may be detectable when the patient is first presented for medical examination and because of this the chest ought to be radiographed at the same time—it certainly ought to be radiographed and the Wassermann taken before any surgical intervention

Isolated or even multiple syphilitic lesions in bone may mimic these appearances of metastases, but as a rule they show some reaction in the surrounding bone, whereas the malignant metastases are usually without any evidence of reaction in the peripheral bone

(10) *Large expanding soft tissue tumour associated with normal underlying bone* The tumour in the adolescent and young adult which presents this appearance is the periosteal sarcoma. Though the tumour reaches great dimensions there may be no change in the involved bone in some cases there is a suggestion of hypertrophy of the compact cortex, and, in the latest phase, there may be a thin periosteal accretion or very faint spicules. The clinical histological and radiographic features may confuse as in the case of the young soldier recorded on p 713

In the adult a large soft tissue tumour without changes in the bone may show in the region of the primary focus an ill-defined deposit of ectopic bone. This is the fibrosarcoma, which is much less malignant and may not return even with localised excision —amputation is usually a success.

Biopsy Because the diagnostic features yielded by the clinical examination were so few and indefinite attention was turned to histology which provides a much higher percentage of accuracy and the practice of a preliminary biopsy gradually asserted itself To-day biopsy is regarded by some as the primary essential investigation, and should the first biopsy yield material, the histologic features of which fail to support the opinions already formed from the clinical features a second or even a third biopsy is regarded as justifiable It is interesting to note that in a number of the reported cases

rarely present in tubercular osteomyelitis this is a mis-statement, for periosteal accretions are common in tuberculous osteomyelitis—they may form a very expanded involucrum within which the original shaft is destroyed, leading eventually to the appearance called spina ventosa. In other cases the accretions may show as multiple parallel deposits, usually over a fairly well-defined area of destruction of the original bone, with perhaps an indication of an ill-defined sequestrum within the focus. In some cases the periosteal accretion in tubercle is fleeting—present at one examination and gone at the next, to reappear with a further phase of activity

Periosteal accretions may be seen over a Brodie's abscess during a phase of reactivity and over a normal bone or a simple cyst or bone tumour which has been subjected to trauma or inflammatory changes a week or so previously The reactive changes following function at the site of an incomplete fracture in a patient who does not remember trauma to the site which is now painful have been mistaken for evidence of sarcoma.

Acute osteomyelitis which has been suspected in its early stages and aborted by treatment with sulphathiazole or penicillin may show a periosteal cuff and irregular spicules in association with an adjacent localised area of decalcification which radiographically may be indistinguishable from sarcoma. While in the early stage the affected diaphysis may show some degree of osteoporosis, as the result of effective treatment it may develop a density which is in contrast with the unaffected epiphyses In leukæmia localised periosteal accretions may be associated with an adjacent area of decalcification.

The periosteal hæmatoma which is undergoing calcification is distinctive—its appearance in scurvy particularly when it occurs in the patient with osteogenesis imperfecta has been described (see p 550).

In Hæmophilia multiple linear accretions may be seen on a bone within an obvious clinical tumour Such have been mistaken for sarcomata.

The histological features of tumours having this periosteal reaction show considerable variation. They are variously reported on as round-celled, spindle-celled, *Ewing* chondroblastic or chondromyxo-sarcoma.

(4) *Periosteal irregular fibre-like spicules radiating from a localised area of damaged cortex usually bounded by a periosteal reaction cuff at both ends* From the surface of a localized area of damaged cortex—which appears to be diminished in calibre, for its borders are usually indicated by a periosteal reactive cuff which is fairly clearly defined —calcified fibres radiate into a large adjacent soft tissue tumour These calcified fibres do not present the fine sharp palisade spicular appearance, for they are irregular in calcification, distribution and outline; small faint flocculular deposits of calcium may be present in the neighbourhood. At a later period calcium may be more widely deposited and outline the large soft tissue tumour Only one surface of a localized area of bone may appear to be involved—the remainder shows normal characters. These tumours may be seen on the middle third of the shaft of a tubular bone, or nearer the ends of the diaphyses. The soft tissue tumour often appears to be massive compared to the size of the bony lesion. They usually present the histological features described as a chondrosarcoma or chondromyxo-sarcoma. They are most common during the years 10 to 30 but isolated examples are seen at other ages.

Fracture of a sarcomatous bone may result in localised decalcification of the ends of the fragments over an area of one or two inches, and the periosteal borders of this area may show considerable fibre-like irregular specular growth.

Some metastases from such lesions as carcinoma of the lung may be associated with a somewhat similar radiographic appearance these are not usually associated with any large soft tissue tumour

may be seen in bony extensions or metastases from epithelioma and in xanthomatosis (see Fig 407)

(c) A combination of (a) and (b) occur more frequently in carcinoma of the breast

(d) Multiple small well-defined round areas of cancellous destruction The medullary cavity of tubular bones may be expanded by scalloping of the inner cortical wall by the multiple rounded tumours. In myelomatosis such lesions may be seen in all elements of the bony skeleton, but they are particularly evident in the ribs, skull and pelvis;

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soft tissue tumour such a lesion is liable to be mistaken for a tuberculous or more acute inflammatory process with its accompanying abscess

Some of these lesions respond to X radiation, and consolidation occurs in sites which appeared to have been completely destroyed. In others the dissolution persists in spite of the radiation. Such tumours present a histological appearance which has been described as osteoclastoma, neuro-sarcoma, chordoma, osteolytic sarcoma. Some metastases from secondary carcinoma and epithelioma (see Fig 407) present these radiographic features. The localised osteolytic destruction associated with osteoclastoma is illustrated in Figs. 212, 218 487 and 488. See also p 698

(7) *Localised irregular disintegration of a previous bony lesion* (see Figs 477 A and B) At the site of an old injury to bone an osteoma chondroma, osteo-chondroma, fibroma, organised subperiosteal hæmatoma, simple or multilocular bone cyst, Paget's disease an old osteoclastoma, a soft tissue tumour develops rapidly and radiographs of it show irregular destruction of the mature bony elements The clearly defined details of the structure of the adjacent bone is in contrast with the mush at the site where malignant metaplasia is developing Such tumours may develop 10 or 20 years after the patient had noticed the original lesion. They usually have the histological feature of a chondro-sarcoma or chondro-myxo-sarcoma. Amputation in some cases appears to give 5 to 15 years cure, but in other cases which are indistinguishable secondaries develop early

(8) *Localised irregular cyst-like extensions and expansions of bone* Large cyst like expansions of bone, quite different in appearance to the simple or multilocular cyst, in that they extend much beyond the normal periphery and to such an extent that they may be two or three times the calibre of the adjacent bone. The latter may appear to be quite normal in appearance, but may have undergone some degree of disuse atrophy The affected segment has lost all its normal structure, it may have the appearance of coarse foam or soap bubbles It has a thin wall which appears to be calcified or incompletely ossified, and fractures occur through it. These lesions may be found in young adults with lympho-sarcoma, but are usually secondary metastases—often from carcinoma of the kidney (hypernephroma)—they may be solitary and the patient may get relief for a varying period by resection or amputation. They do not as a rule respond to X radiation.

(9) *Multiple metastases in the bones or lungs* The commonest sarcoma to metastasise in bones is that described by *Ewing* but carcinoma of the breast, prostate, kidney uterus, suprarenal and thyroid, to give but a few primaries, commonly metastasise in the bones other sarcomata usually metastasise in the lungs. *It is advisable in all cases of bone tumours to take a radiograph of the lungs at the same time as the radiograph of the tumour is taken.* The discovery of metastases has an important bearing upon the surgical or therapeutic procedure to be adopted. But it must be remembered that multiple foci *occur in xanthomatosis or lipoidystrophy* and may develop in the lungs in association with an inflammatory lesion of bone. Sulphathiazole or penicillin may cause resolution.

The radiographic appearance of metastases show considerable variation :—

(*a*) Ill-defined rounded areas of increased density which ultimately expand and merge to produce a bone which is uniformly denser than the normal—this type is seen from primaries in the prostate or alimentary canal

(*b*) Localised areas of osteolytic destruction of the cortex or medulla—the progressive development of the former lesion may lead to complete disappearance of the affected bone The medullary metastases may be isolated or multiple and merge to leave merely a shell of bone which may show more or less expansion—sometimes two or three times the calibre of the normal bone These readily fracture. This type is seen from primaries in the breast, prostate thyroid, kidney and genital organs—similar appearances

following the trauma may have serious influence in the histological appearances the extent of which it may be impossible to assess

These serious limitations (set forth in detail elsewhere [31] by the author) in visualising the development of a lesion are to be added to the equally serious limitations in the microscopic amount of the tumour which can be examined Further the damage to the tissues during the surgical exploration results in added clinical and radiographic features which may seriously confuse evidence otherwise decipherable

Thus *S L Baker* from the histology of his cases deduced that the abnormal tissue (he called it hyperplastic callus) was a mass of woven bone which grew out from the damaged focus but from the radiographic evidence of 4 cases I had recorded previously which permitted of serial observations of the whole lesion, it was possible to deduce the evidence that they were simple and started as hæmatomata in which calcium was deposited prior to its transformation into bone It also gave an indication for a line of therapy which has been successful. When small pieces of tissue only are removed these may not contain any of the tumour cells or be too small to be correctly related to the main mass When large pieces are removed it may entail serious damage to the scaffold for regeneration of simple lesions and cause complications from hæmorrhage etc.

Errors in histologic interpretations may be due to the following factors —

(1) *Faulty selection of material. If the lesion is small and biopsy is decided upon,* the focus should be accurately localised for the surgeon by the radiologist. In the case illustrated by the author[28] the radiograph shows that the bone resected and reported as normal was removed from a site well away from the lesion in the bone : a later and more extensive biopsy provided material which confirmed the malignancy of the tumour

(2) Insufficient data supplied to the pathologist. We know that X-radiation and other therapeutic measures may mask the malignant nature of the lesion, and the histology of callus at the site of a recent fracture may simulate malignancy

(3) Necrotic material may be mistaken from its macroscopic characters for pus. Any such material should be submitted for histological examination.

(4) Failure to obtain the radiologist s co-operation. The radiological features may be characteristic or indefinite. When the radiograph strongly indicates malignancy it should not be disregarded.

Unfortunately there is evidence that biopsy may not only yield material which permits of error in interpretation, but also causes local and possibly general dissemination of tumour cells. Serial radiographs of tumours before and after accidental or surgical trauma show marked acceleration and extension of the visible bounds of the tumour after the trauma, and it is not unreasonable to believe that there is a relation between the trauma and the appearance of metastases in the lung a few months later There is evidence that malignant metaplasia may occur at the site of a fracture of a bone which previously appeared to be free from such changes. I have seen such development occur in the broken end of one fragment, while the other fragment appeared to retain its normal characters

Perhaps the most valuable contribution is made by biopsy when its findings indicate simplicity and prevents the unnecessary amputation of a limb rather than when it confirms the clinical and/or radiographic evidence of malignancy The report of simplicity however does not always satisfy the surgeon and a second or third surgical exploration may be done : whereas if the material is reported as malignant the diagnosis may be considered as established and amputation proceeded with at once though it may be a simple lesion which, left alone would have resolved. From this we can see the force of *S L. Baker's* comment "Had the leg been removed in my Case 1 it would have b impossible to prove that it was not a sarcoma cured by amputation." Though

of osteogenic sarcoma which have been cured two or more biopsies have been performed (this opinion has been more recently confirmed by *Ferguson* from examination of the cases reported to the Registry of Bone Sarcoma) yet in those cases of osteogenic sarcoma which present typical radiographic characters death has occurred from metastases in spite of the performance of amputation without a preliminary biopsy Yet we cannot *infer from this that biopsy is a healing factor* To appreciate the possibilities of incorrect interpretation of the nature of the tumour let me briefly outline the development of the skeletal tissues

The study of embryology teaches us that near to the primitive groove a middle layer of cells develops between the ectoderm on the one side and the entoderm on the other This middle layer constitutes the mesoderm. Its primitive cells, differentiating in the normal embryo are destined to build among other structures, the connective tissue fat, fibrous tissue, fascia, tendon, cartilage and bone.

It has been experimentally proved that, with normal environment development of each cell proceeds according to a predetermined and irrevocable order and in so doing influences and is influenced by its immediate neighbours This controlled development persists throughout life, and the evidence we have before us suggests that should any element lose its controlling factor irregular development ensues and neoplasm appears. The stage of development nature of differentiation and the immediate association of the mesodermal cells at the time the mutation occurs would appear to influence the character of the cells, which ultimately form the tumour Consequently these tumours may not only be built up of units which represent the characters of such cells as fibroblasts, cartilage or bone cells, but the more primitive antecedents of such cells. Further by histological examinations of tissue removed from the site of a recent fracture we know *that mesodermal cells in all stages of differentiation may be found therein.* It will, therefore not come as a surprise to know that great difficulty may be experienced in distinguishing tumour processes from normal repair processes.

No less an authority on the histology of tumours than *Ewing* states —"In the average specimens of callus, the proliferative activity of fibroblasts, osteoblasts and endothelium *is quite remarkable* and often presents *a picture which is difficult to* separate from sarcoma—some organising blood clots after fracture I have found quite difficult to separate from sarcoma."

Histologic examination of material removed from some tumours and submitted to different expert pathologists will yield reports on the cellular structure ranging from simplicity to high malignancy *In the series which I recorded will be found examples* of simple tumours which presented histological characters indistinguishable from malignancy and which were interpreted as such. While, in others, the histological features of malignant tumours were interpreted as those of simple tumours. Such interpretations are due to the fact that identical cellular features are to be found in both simple and malignant tumours, and *while the examination of multiple selected fragments* may yield but one showing cells which are regarded as possessing malignant characters, this may rightly or wrongly be chosen to determine the diagnosis

It is noticeable that while the histology of healthy bone permits of the use of such descriptions as fibrous cartilaginous or osseous tissues pathological influences on the tissues produce indecision in the histologist which is characterised by the use of such terms as fibroid, chondroid, fibro-chondroid osteoid and chondrosteoid

From the very nature of biopsy and all that it entails to the patient it can only be employed on one or two occasions and these not for weeks after the onset of the lesion, during which the initial changes at the site have been obliterated by the subsequent development If more than one surgical exploration has been made the reactions

the result of trauma, the most common site being on the outer side of the shaft of the femur or it may be a widespread condition involving most of the limbs and trunk. When fully developed the ossified tissue resembles normal bone in its radiographic appearances (see Figs. 310 and 311)

Ossified hæmatomata may be mistaken for sarcomata (see Fig 405)

Osteoma of the falx, which is a localised ossification in the falx cerebri, may be seen as a buttonhole-shaped opacity in the mid line on the postero-anterior radiograph of the skull.

Similar osseous changes may be seen in the cerebral and spinal dura, while, occasionally progressive ossification can be shown radiographically throughout the whole lung structure as a reticulated osteoma.

Chondroma (see Figs 42–45) Tumours composed of cartilage and called enchondromata are very commonly seen developing within the phalanges, causing a localised destruction of the bone striæ and expansion of the shafts, but they are usually well defined and have a definite bony capsule from which they may be shelled out entire (see Fig 42). Though their histological structure suggests immaturity they are benign.

The presence of these chondromata may be first indicated by a fracture of the phalanges from relatively slight trauma. Radiographs of the remainder of the skeleton may show other similar tumours. Larger chondromata are seen developing at the chondro-sternal junction, an example of which is shown in Fig 417

Wakeley [1] has published an account of such a case, with radiographs, in which there was a definite history of trauma 7 years before, and as there was marked pulsation of the tumour it was mistaken for a sarcoma. The radiographs show flaky calcium deposits as in chondroma.

These tumours may attain the size of an orange and then cease to develop After this, irregular calcification usually occurs which assists the decision as to the nature of the tumour from its radiographic appearances.

Isolated chondromata in the long bones produce a radiographic appearance which simulates soap-bubbles more closely than does the osteoclastomata (see Fig 185). The bony boundaries of chondromata are rounder and more sharply defined because they show reactive sclerosis. The adjacent extremity of the shaft is expanded and its compact tissue increased. None of the trabeculæ of the original bone at the site traverse the tumour as they are absorbed during the expansile growth of the rounded cartilaginous nodule but isolated bony fragments may be included within the tumour if this had resulted from the growth of adjacent cartilaginous nuclei (see Fig 45).

The sub-cortical chondroma protrudes from the normal periphery though the remainder of the shaft is constituted of normal bone They do not show the same juxta-epiphyseal distribution which is associated with osteoclastoma. They often grow in the neighbourhood of the nutrient foramina (see Fig 44)

Chondromata developing from the intervertebral discs may cause some erosion of the vertebral bodies and may press upon the spinal cord.

Proliferation of the injured cartilaginous plate of the intervertebral disc may lead to irregular cartilaginous invasion of the cancellous tissue of the vertebral body (Schmorl's Nodes) (see Fig 384)

Chondromata of large size also develop in close association with the symphysis pubis or the sacrum and cause much danger by obstructing labour Such chondromata may appear to be benign from their structure. They must be completely removed otherwise recurrence and invasion of veins may occur

Their presence may be indicated on the radiograph by the shadows of irregular flaky calcification, a deposit of carbonate and phosphate of lime, which these tumours

incentive for biopsy is the desire to obtain evidence of malignancy at the earliest moment which will admit of prompt amputation, the pathologist's report of malignancy is not always accepted, particularly if the clinical condition does not appear to warrant such a drastic course On the other hand, though the clinical and radiographical evidence indicates a malignant growth, if the pathologist reports that the lesion is benign, serious delay may result. The author [11] has given an account of one such case where amputation of a malignant lesion was deferred for 7 months on this account. It involved 4 surgical attacks (2 biopsies a resection and later amputation).

The distinctive radiographic features of osteoclastoma, angioma, plasmocytoma, adamantinoma, chondroma, simple and multilocular cysts, and malignant metaplasia in Paget's disease of bone have been fully described in other chapters.

Papers containing radiographs illustrative and descriptive of the various types of bone tumour have been published by *Babok, Bloodgood, Codman, Geschickter and Copeland Kolodny Ogilvie and Sutherland.*

Osteoma. Of the simple tumours the most common met with is some form of osteoma of either the single or multiple variety They may be flat and sessile pedunculated, simple or branched, at the free extremity They may appear as a general thickening of the bone—the so-called hyperostosis examples of which are seen fairly frequently affecting the bones of the skull. They are said to result from trauma inflammatory reaction, or the reaction following the development of a neurofibroma or an endothelioma in the adjacent membranes

The condition of **Leontiasis Ossea,** in which the radiograph may show a marked thickening and sclerosis of any or all the face bones is said to be a reaction to sinus infection (see Figs 442 A and B).

Enostoses are bony tumours which lie within the normal bones the most important being those associated with the roots of teeth. The islands of compact tissue, seen as single specimens in one or other of the bones of the extremities or in some cases, throughout the whole cancellous bone of the skeleton (**Osteopoikilie**) cannot be considered as enostoses, as they do not appear to extend their development or interfere with function (see Fig 310)

Exostoses, single or multiple, may be found in association with most bones. The radiographs show that these projections are of similar structure to normal bone and it is impossible in most cases to say where the exostosis begins and the normal bone ends. Cartilage enters into the structure of many of them Multiple exostoses often have a familial tendency and they are important in that they develop near the growing ends of bones, and, in some cases, limit the movements of joints and produce deformity (see Figs 160 and 202). The nature of the osteoma, whether of the ivory type (exostosis eburnea), spongy or cancellous (exostosis spongiosa), or that containing wide marrow spaces (exostosis medullaris) can be determined from the radiographic appearances of the tumour

Single exostoses develop in definite, well recognised sites as the result of trauma, particularly at the insertion of tendons Rider's bone is a familiar example (see Fig 211)

The true osteoma, of the ivory type, is most commonly seen developing in association with the orbits and the accessory sinuses (see Fig 452) These may give rise to grave disturbances of function owing to their size or location They may be difficult to remove completely and, as in the example shown, they may recur They may be associated with multiple mucoceles, as in the case recorded by *Armitage* or with a pneumatocele as in *Cushing's* case

The condition of myositis ossificans produces a radiographic appearance which simulates that of the osteomata and sometimes sarcomata It may occur locally as

Neurofibromata sometimes develop beneath the periosteum and the dura of the central nervous system. These tumours may cause erosion of the adjacent bone and hyperostosis of the surrounding bone (see Fig 450). The elevated periosteum may exhibit subperiosteal ossification and the radiographic appearance of a subperiosteal cyst is produced.

Brooks and *Lehman* have described a series of cases of neurofibromatosis in which the radiographs show the appearances of central and subperiosteal cysts.

The multiple lesions of polyostotic fibrous dysplasia are described on p 581

Myxoma. Tumours consisting of mucoid connective tissue may be found in the phalanges, the tibia, femur humerus, or spine.

It is impossible from the radiograph to distinguish them from chondromata, and in some cases they have the radiographic appearances of bone cysts. Some of these have been known to recur after surgical evacuation.

The multi-cyst like tumour referred to as osteitis fibrosa cystica may show the histological characters of a myxoma and recur after surgical evacuation, as in the specimen shown in Fig 170 See Polycystic Dysplasia p. 570

Periosteal Lipoma. Lipomata which develop in association with the periosteum may cause absorption of the subjacent bone. The radiographs, if taken with a soft tube, show a shallow excavation of the surface of the affected bone and a fan like striation of the tumour mass, which may show as a rounded body of greater transparency than the surrounding soft tissues In some cases calcification occurs in the tumour No bone changes may be produced (see Fig 98)

Radiographs illustrating these features, together with the clinical details of 2 cases, are to be seen in *Partlett's* paper

Angioma. Angioma of the bones though frequently discovered on section of the spine at post-mortem, is a relatively rare radiographic finding The radiographic appearances of these tumours are distinctly different when occurring in the vertebræ and in the limb bones, but each is characteristic.

In the limb bones and skull (see Figs 451 A and B) the tumour mass has the appearance of a shaggy head of hair in which there is a centrum with coarse slightly wavy bony trabeculæ radiating from it. The tumour bone is expanded has a fairly clear border and is rather less dense than the normal bone It preserves this appearance throughout its development If developing in close proximity to other bones it causes pressure absorption of them. Specimens of these tumours have been seen in the skull, humerus scapula and the lower end of the tibia. They have been recorded in the facial bones in association with hæmangiomatous nævi

A hæmangioma of the lower end of the tibia was resected by *Naughton Dunn* who bridged the gap so caused with a bone graft, and complete functional recovery occurred

Hæmangioma involving the whole of the bones of an extremity have been seen by the author The bones of the pelvis, femora, tibia and fibula and bones of the foot showed a semi transparent lace-like cancellous structure but no definite compact bone In one case the shafts of the tibia and fibula showed a relative osteoporosis with irregular areas of cancellous structure, a few spindle-shaped areas of decalcification under the periosteum but no periosteal accretions at the site. These changes were associated with those of chronic arthritis of the knee joint and multiple phleboliths in the soft tissues. The appearances of the tibia had been reported as those of osteomyelitis. The lack of periosteal reaction and the presence of the phleboliths should have prevented this.

The bones of an extremity the soft tissues of which are involved by lymphangioma, may show greater development than those of the opposite normal limb Further the

usually show Large chondromata may be present at this site with little bone change to indicate it.

Ernst and also *May* have described a chondroma of the lumbar spine which invaded the veins of the pelvis and abdomen, and *Platt* [3] has described several large chondromata which have developed in connection with the upper end of the femur producing in one case a fracture of the femoral neck. The possibility of the tumour being a chondroma may be further suggested by the demonstration of chondromata in other places.

Cases of multiple chondromata have been described in which the tumours have been demonstrated in most of the bones of the body Subperiosteal chondromata may cause erosion of the bone and spontaneous fracture, as in the case illustrated by *Platt*,[3] or an osteochondroma may develop which will show on the radiograph as an exostosis with an irregular ill-defined border but these are usually associated with deposits of amorphous calcium which help to settle the diagnosis.

If the radiographic appearances of such a tumour change and an irregular destruction of the involved diaphysis spreads to the epiphysis, the question of chondro-sarcoma has to be considered The radiographs of *Rocyn Jones's* patient, a boy aged 8½ years, show the typical changes which osteochondromata undergo in the course of 6 years.

Surgical removal of the simple chondroma or osteochondroma usually results in a cure, but in some cases recurrent tumours develop which may present a different histological structure.

The radiographs of some of these chondromata suggest malignancy because of periosteal involvement and bone erosion, but the pathologist may report on sections of the tumours that they are simple chondromata, yet later recurrences of the tumours verify the radiographic reports

A report on such a tumour which was present in a patient at the Queen's Hospital Birmingham was published by *Neale* and *Allen Price*

May has published the radiographs and details of an interesting case.

A Greek, aged 40 years in 1914 had a small tumour removed from the second metatarso-phalangeal joint which was diagnosed histologically as an osteochondroma. He remained quite well until 1928 when he noticed a non-tender swelling at the site of the operation. This grew rapidly and a radiograph taken in December 1928 showed a very dense tumour with a spiky periphery which had involved most of the bones distal to the mid-tarsal joint. A mid-leg amputation was performed and sections were reported as showing a sclerosing osteogenic sarcoma. In April, 1929 pulmonary metastases were demonstrated, and in May 1929 at a post-mortem examination metastases were found in the vertebræ lungs and kidney

The histological appearance of some cases of chondroma suggests malignancy when the radiographic evidence is more indicative of simplicity

In some cases multiple hæmangiomata occur in association with multiple chondromata. These can usually be distinguished by the presence of small rounded bodies phleboliths often having a central opacity and a dense periphery (see Fig 42, E).

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Further details and illustrations of the radiographic appearances are given on pp. 48 and 52

Fibroma. Fibromata may develop in association with the periosteum. Such a tumour may lead to pressure erosion of the bone and pathological fracture. Single large fibromata of this nature develop in the region of the neck of a rib, and appear on the radiograph of the thorax as a rounded shadow which resembles that of a hydatid cyst.

Neurofibromata sometimes develop beneath the periosteum and the dura of the central nervous system. These tumours may cause erosion of the adjacent bone and hyperostosis of the surrounding bone (see Fig 450) The elevated periosteum may exhibit subperiosteal ossification and the radiographic appearance of a subperiosteal cyst is produced

Brooks and *Lehman* have described a series of cases of neurofibromatosis in which the radiographs show the appearances of central and subperiosteal cysts.

The multiple lesions of polyostotic fibrous dysplasia are described on p. 581

Myxoma. Tumours consisting of mucoid connective tissue may be found in the phalanges, the tibia, femur humerus, or spine.

It is impossible from the radiograph to distinguish them from chondromata, and in some cases they have the radiographic appearances of bone cysts. Some of these have been known to recur after surgical evacuation.

The multi-cyst-like tumour referred to as osteitis fibrosa cystica may show the histological characters of a myxoma and recur after surgical evacuation, as in the specimen shown in Fig 179 See Polycystic Dysplasia, p. 570

Periosteal Lipoma. Lipomata, which develop in association with the periosteum, may cause absorption of the subjacent bone. The radiographs, if taken with a soft tube, show a shallow excavation of the surface of the affected bone and a fan like striation of the tumour mass, which may show as a rounded body of greater transparency than the surrounding soft tissues In some cases calcification occurs in the tumour No bone changes may be produced (see Fig 98).

Radiographs illustrating these features, together with the clinical details of 2 cases, are to be seen in *Partlett's* paper

Angioma. Angioma of the bones though frequently discovered on section of the spine at post-mortem, is a relatively rare radiographic finding The radiographic appearances of these tumours are distinctly different when occurring in the vertebræ and in the limb bones, but each is characteristic.

In the limb bones and skull (see Figs 451 A and B) the tumour mass has the appearance of a shaggy head of hair in which there is a centrum with coarse, slightly wavy bony trabeculæ radiating from it The tumour bone is expanded, has a fairly clear border and is rather less dense than the normal bone It preserves this appearance throughout its development. If developing in close proximity to other bones it causes pressure absorption of them Specimens of these tumours have been seen in the skull humerus scapula and the lower end of the tibia. They have been recorded in the facial bones in association with hæmangiomatous nævi.

A hæmangioma of the lower end of the tibia was resected by *Naughton Dunn* who bridged the gap so caused with a bone graft, and complete functional recovery occurred

Hæmangioma involving the whole of the bones of an extremity have been seen by the author The bones of the pelvis, femora, tibia and fibula and bones of the foot showed a semi transparent lace like cancellous structure but no definite compact bone In one case the shafts of the tibia and fibula showed a relative osteoporosis with irregular areas of cancellous structure, a few spindle-shaped areas of decalcification under the periosteum but no periosteal accretions at the site. These changes were associated with those of chronic arthritis of the knee joint and multiple phleboliths in the soft tissues. The appearances of the tibia had been reported as those of osteomyelitis. The lack of periosteal reaction and the presence of the phleboliths should have prevented this.

The bones of an extremity the soft tissues of which are involved by lymphangioma, may show greater development than those of the opposite normal limb. Further the

usually show Large chondromata may be present at this site with little bone change to indicate it

Ernst, and also *May* have described a chondroma of the lumbar spine which invaded the veins of the pelvis and abdomen, and *Platt*[2] has described several large chondromata which have developed in connection with the upper end of the femur producing in one case a fracture of the femoral neck The possibility of the tumour being a chondroma may be further suggested by the demonstration of chondromata in other places

Cases of multiple chondromata have been described in which the tumours have been demonstrated in most of the bones of the body Subperiosteal chondromata may cause erosion of the bone and spontaneous fracture, as in the case illustrated by *Platt*,[2] or an osteochondroma may develop which will show on the radiograph as an exostosis with an irregular ill-defined border but these are usually associated with deposits of amorphous calcium which help to settle the diagnosis

If the radiographic appearances of such a tumour change and an irregular destruction of the involved diaphysis spreads to the epiphysis, the question of chondro-sarcoma has to be considered. The radiographs of *Rocyn Jones s* patient, a boy aged 8½ years, show the typical changes which osteochondromata undergo in the course of 6 years.

Surgical removal of the simple chondroma or osteochondroma usually results in a cure, but in some cases recurrent tumours develop which may present a different histological structure.

The radiographs of some of these chondromata suggest malignancy because of periosteal involvement and bone erosion, but the pathologist may report on sections of the tumours that they are simple chondromata, yet later recurrences of the tumours verify the radiographic reports

A report on such a tumour which was present in a patient at the Queen's Hospital Birmingham was published by *Neale* and *Allen Price*

May has published the radiographs and details of an interesting case

A Greek, aged 40 years, in 1914 had a small tumour removed from the second metatarso-phalangeal joint which was diagnosed histologically as an osteochondroma. He remained quite well until 1928 when he noticed a non tender swelling at the site of the operation. This grew rapidly and a radiograph taken in December 1928 showed a very dense tumour with a spiky periphery which had involved most of the bones distal to the mid tarsal joint. A mid-leg amputation was performed and sections were reported as showing a sclerosing osteogenic sarcoma. In April 1929 pulmonary metastases were demonstrated and in May 1929 at a post-mortem examination metastases were found in the vertebræ lungs and kidney

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of a spontaneous fracture the presence of a visible or palpable tumour or a dull boring pain at the extremity of one of the bones In the majority of cases in which this tumour is found the epiphyses have fused, the growth cartilage has disappeared and the tumour has caused extensive destruction of the cancellous tissue in the area of the epiphyseal growth cartilage so that it is impossible to determine the exact localisation of the primary focus. Often the extent or site is such that surgical interference will destroy the joint.

In contradistinction to such authorities as *Ewing Geschickter* and *Copeland*, I am of the opinion that it begins in the juxta-epiphyseal area of the diaphysis and not in the epiphysis, for I have found it confined to the former but never to the latter The larger extent of the tumour in the epiphyseal area at the time the tumour is first detected does not conclusively prove that the tumour arises in the epiphysis The cancellous nature and the vascularity of the epiphysis might well account for its more rapid destruction. The tumour acts essentially as a solvent of bone During its active phase it does not cause any other reaction in the adjacent bone except perhaps in the thin layer of subarticular bone, and to a lesser extent the subperiosteal bone, so that we see no evidence of sclerosis or other protective phenomena. Though there is no clearly defined bony wall on the shaft side, such as we see around a chondroma growing at this site, the bounds of the tumour can be appreciated by the extent of the concavity in the bone due to the cancellous dissolution which tends to follow a regular curve.

Because of this regular excavation of the bone around the periphery of the tumour the radiograph shows a graded diminution of density of the extremity of the shaft towards the main mass of the tumour

Often the lesion appears to be subcortical and confined to one side of the affected bone only but in other cases it is obvious that the tumour has destroyed the whole of the cancellous tissue in the extremity and fills the bony shell remaining When this has occurred expansion of the extremity soon follows, as a result of the growth pressure on the thin containing shell. But in the early stages no change can be detected in the periphery of the affected extremity which, being bridged by residual trabeculæ, preserves its normal outline and dimensions (see Fig 212) The bone will, however show localised expansion on the tumour side when a considerable area of bone has been destroyed (see Fig 218). In the area occupied by the tumour the delicate cancellous architecture has been destroyed and only a relatively few strands of bone are seen in a coarse mesh, which represent the remaining supporting bony trabeculæ. The bony boundaries of the tumour present certain characteristics The lateral walls are gradually and in some cases completely absorbed. The subarticular bony boundary appears to show a better resistance for a time it appears to show a protective sclerosis, and even in the later stages the preservation of this bony outline indicates that the articular cartilage is intact and the joint not invaded (see Fig 448) The boundary of the shaft is concave and presents the graded density previously described. Generally there is no evidence of periosteal irritation—the compact cortex of the shaft preserves its definition, density and contour to the bounds of the tumour where it shows the same solvent appearance as we see in the cancellous tissue Occasionally a periosteal reaction on the adjacent cortex is present The tumour grows expansively but its cells do not invade the bone in the manner characteristic of endothelial myeloma or osteogenic sarcoma

The remaining trabeculæ, which are seen to traverse the area invaded by the tumour in the early stages are gradually and in some cases completely absorbed, leaving an expanded cyst-like bony shell, the uneven absorption of which may give it a somewhat crenated appearance which has been likened to foam. This, however is not obvious in the actively growing lesion, though it may be emphasised at a later date when prolifera

function of such bones is disturbed and irregularity of development occurs associated with subluxation and actual dislocation of the large joints (see Fig 216)

The bones of an extremity which is involved in extensive capillary angiomata may show atrophy of the terminal phalanges which are deficient in calcium and show defects in the cancellous pattern *even to the extent of small cysts. This may be particularly* noticeable in the extremities of the tubular bones Fig 46 shows the appearance of the hand of a patient who had a thick port wine angioma involving the whole of one superior extremity

Radiographs illustrating the typical appearances are to be seen in the papers by *Pohl, Hitzrot, Bucy* and *Capp.*

The typical appearance of vertebral hæmangioma is described and illustrated in the chapter on the spine (see Fig 414)

Ewing has described a case in which an angioma developed in the head of the *humerus 2 years after a severe trauma.*

A subperiosteal angioma may cause erosion of the bone and be the cause of a pathological fracture.

Surgical removal of these tumours usually results in a cure.

Good results have also been recorded from X radiation.

Hyperostosis of the skull has been seen in association with hæmangiomatous nævi, and irregular ossification of the bones is seen in limbs involved by diffuse lymphangioma or hæmangioma. The appearance at the diaphyseal extremities of the long bones bears a superficial resemblance to the bones in some cases of multiple chondromata, such as *the one illustrated by C P Harris*

Osteoclastoma. This tumour which is characterised histologically by a predominant proliferation of multinucleated giant cells, was formerly called myeloid sarcoma, myeloma, and lately simple giant-celled tumour The exact relation of this tumour to trauma and its resultant subperiosteal or medullary hæmorrhage is unknown, but it is usual for the patient to give a history of an injury to the site beneath which the tumour has developed.

It may be found in any bone, but the most common sites are in the juxta-epiphyseal areas at the lower ends of the femur (particularly the lateral aspect), radius and tibia, and the upper end of the tibia and fibula. In these sites the radiographic appearances are usually characteristic and rarely give the experienced radiologist any difficulty in recognition, but in the less frequent sites such as the vertebræ the pelvis or even the bones of the hands and feet, the diagnosis may not be so readily established.

A number of cases have been reported in which the clinical, radiological and histological features were indistinguishable from others which healed after curettage but from which, following an amputation or resection, metastases have developed in distant sites such as the lungs.

Some authorities deny the possibility of metastases from this tumour but they do occur and it is conceivable that they arise as a result of malignant metaplasia of the tumour cells The fact that many of these tumours have been severely damaged during such surgical procedures as curetting without any recurrence or metastases confirms the simple nature of some osteoclastomata. Local recurrence has followed incomplete extirpation of the tumour tissue, but that is what one would expect with any other *simple tumour*

Radiographic Appearances The tumour is rarely discovered in its early stages for it causes then no prominent signs or symptoms. When it is discovered by X ray examination it has probably existed for a long time several months or even years maybe most patients have reached the 20–30 age period. The examination is sought for because

area may be wiped out the cortical and subarticular bony capsule may appear to have been completely destroyed and the adjacent bony walls still further invaded



FIG 187 (a) June 3rd, 1912. Typical osteoclastoma of lower end of radius extending of tumour with absorption of trabeculae (b) June 20th 1912. After radiation. Apparent (c) July 29th. Further absorption of trabeculae with fracture of lateral wall of cavity (d) December 17th. Progressing consolidation (the *Lancet*)

Such are the changes which may be seen in radiographs taken during the first 2 months following the X radiation. In addition *the clinical appearances may appear to indicate during this period a progressive expansion* the area is *more swollen and the skin reddened,*

tion has diminished or ceased and reactive bone and calcium has been laid down in the boundary walls. The latter then appear to be much thicker and more clearly defined.

The stability of the bone may be destroyed at the site and spontaneous fracture occur during normal movements. Organisation of the hæmorrhage so produced may later attract deposits of amorphous calcium within the tumour which increases the density and blurs the definition of its bony walls. The expanded shell of bone often shows some degree of compression deformity such as one would expect at such a weakened site. Its contour may be broken and the ends of the shaft may show a degree of telescoping into its bony shell.

In those cases in which the limb has been immobilised during the treatment of the lesion, diffuse osteoporosis of the bones may complicate the picture and produce a radiographic appearance resembling that of a carcinomatous metastasis.

In the leg and forearm expansion of an osteoclastoma in one bone may lead to pressure absorption of the adjacent bone. In those tumours which have been complicated by the invasion of septic organisms, sequestrum formation, periostitis, and osteitis may mask the picture. Apart from these characteristic juxta-epiphyseal sites, examples of tumours having similar histological appearances have been reported in the shafts of the long bones, either in a subperiosteal or medullary location. Some of these tumours, in spite of their histological appearances, have a different significance. Some of them are known to be related to tumours of the parathyroid, and have gradually disappeared following removal of the activating parathyroid. Yet in others the subsequent clinical history and radiographic appearances suggest that the histological material was from the periphery of the lesion, and did not contain tumour tissue. Other tumours in these sites have been labelled as osteoclastoma solely because their radiographic appearances somewhat resembled those of osteoclastoma: a proportion of them have been plasmocytomas and chondromas.

Differential Diagnosis. Chondroma, angioma, simple bone cyst, multilocular cysts, cysts due to hyperparathyroidism, osteitis fibrosa cystica, carcinomatous metastases in bone, plasmocytoma, adamantinoma, chronic inflammatory processes, subperiosteal endotheliomata which have been subjected to X radiation, even hæmangio-endothelioma and sarcoma, are lesions which produce radiographic appearances which to the casual observer resemble those of osteoclastoma. The characteristics of the tumours are described in other chapters (see Index).

Treatment. The author [34] published a series of cases which demonstrated clearly that a certain number of osteoclastomata in sites readily accessible to surgery cannot be eradicated by drastic curettage of the bony cavity and carbolisation of the walls, *and that subsequent amputation does not prevent the development of lung metastases.* The histology was anticipated from the radiographic features. Operation solely for biopsy afforded no useful assistance. The tumour material was radically removed and submitted for histological examination. It showed the typical features of osteoclastoma merely confirming the radiological diagnosis, yet amputation was performed and failed to prevent the spread.

The details of one case illustrated the value of X radiation therapy. The radiographic appearances were typical: there was no call for biopsy and none was performed. The patient was submitted to deep X ray therapy. This produced radiographic appearances which are liable to be misinterpreted by those who have not experienced it, namely an apparent stimulation of the growth of the tumour. *Herendeen* pointed out the fallacy of these appearances as long ago as 1924. It must be realised by all who are called upon to treat these tumours that *X-radiation therapy results in an extension of the osteolytic absorption of the involved bone*: all the bony trabeculæ of the tumour

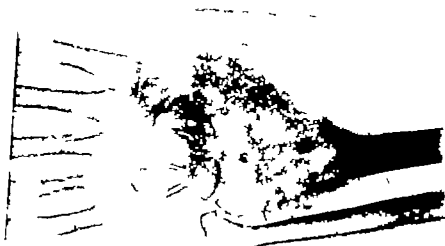


FIG 189 (A) Destructive lesion in upper one-third of humerus diagnosed clinically and radiographically a sarcoma (October 27th, 1938). No biopsy. X-radiation advised (Dr Russell Green case). Chan Yau and Chia-Kwang Hsieh published radiographs of a patient which showed a similar destruction of the scapula in 1932. It was treated by X-radiation and radiographs in 1938 indicated complete healing. No recurrence. Biopsy: "Primary reticulum-celled sarcoma of bone."



FIG 189B. Same lesion as 189 (A), July 1943, after X radiation therapy. All signs of malignancy and tumour have disappeared clinically and radiographically. Note that the bone has been repaired on the old scaffolding and has since undergone moulding towards the normal shape.







properties, failure to produce tumour bone, and a relatively slow but fatal course which is checked to some extent by X radiation

Since *Ewing* first described the endothelial myeloma many papers have been



FIG. 491. Endothelioma of knee joint. Note the filling-up of capsule of joint. Clinically and macroscopically regarded as tuberculous. Multiple metastases in lung; fatal.



FIG. 492. Syphilitic periostitis of the femoral shaft. Note the marked thickening of the cortex

published in which the authors have reported a number of such tumours, though they are by no means common.

A study of the details and radiographs of many of these cases convinces one that the term Ewing's Tumour has been applied to widely different bone lesions varying in malignancy from chronic inflammatory masses to osteogenic sarcomata.

smaller are often confluent. The mandible also shows multiple rounded foci of the larger type while the skull shows many areas which tend to be a little smaller. There is no sign of reaction around these lesions (see Fig 440)

The lesions, which may be mistaken for myelomatosis, are those of carcinomatosis and hyperparathyroidism.

Affected vertebral bodies may collapse spontaneously. Relief of pain may be given by X-radiation. The solitary tumours may respond very favourably to X-radiation as in the vertebral cases reported by *Rosselet* and *Decker* but the myelomatosis does not respond so favourably.

Xanthomatous Tumours of Joints. Xanthomatous tumours may be found in association with tendons and the synovial membrane of joints. They do not produce any characteristic radiographic feature and, as a rule, the only abnormality shown on the radiograph is a soft tissue tumour. In some cases the tumour may lead to pressure erosion of the bone and present an appearance simulating osteoclastoma, but the bone lesion will be small compared to the size of the soft tissue tumour.

They are most frequently found in the lower extremity, the knee being the commonest site; a few have been recorded in the elbow, ankle, tarsal and big toe joints. The patient's attention may be attracted to the joint by restriction of movement; there is often a history of some disability in the joint for some years, and on examination a soft tumour may be felt, in the knee, on the medial aspect of the patella. Signs of effusion may be present and when sanguinous fluid is withdrawn a further quantity repeatedly collects within a few days. The blood cholesterol may be high but the condition does not appear to be related to Xanthomatosis. The tumour may be solitary, multiple or diffuse, and if effectively removed results in cure—recurrence is not uncommon where surgery is more conservative. No case of malignant metaplasia has been recorded. The tumours may be found at all ages but the majority recorded have been in patients over 20 years of age.

These lesions must be distinguished from endothelioma, chondromatosis and loose bodies.

Geschickter and *Lewis*, *De Santo* and *Wilson* and *J. J. Morton* have illustrated and described examples of these tumours.

Neurilemmoma. This tumour is said to arise from the nerve sheath. When it comes into close relationship with a bone it may slowly cut into it, giving a similar appearance to that which would be produced by nibbling the bone with bone forceps. The adjacent bone may show little or no reaction. It is a slow process which may show little advance in 4 or 5 years. It may result in spontaneous fracture of the bone. Such tumours may cause considerable erosion of the walls of the pedicles bordering the intervertebral foramina. *De Santo* and *Burgess* reported 2 cases. Localised excavation of the middle third of the cortex of the ulna in a man of 37 years. Radiographs after 5 years showed little change, while after 7 years only a slight increase in size had occurred together with evidence of buttressing of the weakened shaft. In the other case, a woman of 48, the tumour arose from the dorsal root of the fifth lumbar nerve. There was a 3-year history —the tumour was successfully removed.

Endothelioma of Bone. *Ewing* has classified the endothelioma of bone into three types:—

(1) Angio-endothelioma, which is solitary, cystic, or telangiectatic.
(2) Multiple endothelioma.
(3) Diffuse endothelioma or endothelial myeloma (Ewing's Tumour).

He says that the entire group of endotheliomata is characterised by a medullary location, a tendency to multiplicity, a cellular and vascular structure, marked osteolytic

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He says that the entire group of endotheliomata is characterised by a medullary location, a tendency to multiplicity, a cellular and vascular structure, marked osteolytic

abnormal pulsation. This occurred in the tibia of a patient of the author's and amputation was avoided (see Fig 408)

Massive cervical hæmangio-endothelioma was recorded in a newly born infant by *C A Smith* The mass obliterated the angle of the neck extending from the mid-line in front to the mid line at back. It was beneath the platysma from beneath which it was shelled out with ease, but the infant died 2 hours after

Sarcoma (see pp 685–01) The radiographic appearances of sarcoma depend on the type of cell and the malignancy of the tumour (see Figs 66, A and B 188 193 228, 323 3?0 410 and 485)

The suggestion has been made that, whereas, with benign tumours and inflamma-

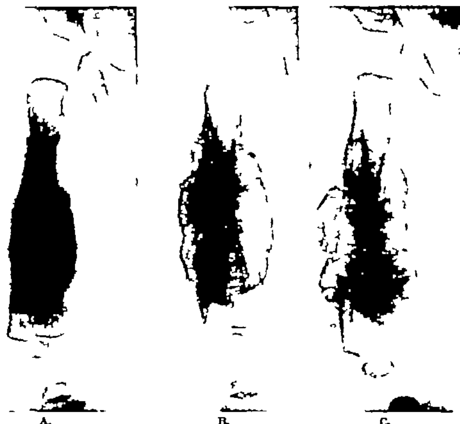


FIG. 404 Radiograph of an infant aged 8 months. Scurvy
A. July 15th, 1947 Calcification in hæmatoma enveloping femoral shaft
B. July 29th, 1947 Further calcification in hæmatoma.
C. August 8th, 1947 Ossification of hæmatoma enveloping femoral shaft.
The patient had been treated with vitamin C after July 29th, 1947 and all symptoms had disappeared.

tory lesions, the epiphyseal cartilage, separating the epiphysis from the diaphysis, acts as a barrier which prevents tumour cells or bacteria advancing across it, with malignant tumours this barrier action of the epiphyseal cartilage is not seen. This suggestion may lead to grave misinterpretation of radiographic appearances, for it is not uncommon to see in the radiographs of rapidly growing sarcomata of long bones, bony changes which are apparently entirely limited to the diaphyses, the structure and density of the epiphyses being that of normal bones.

appearance of certain cases of bone sepsis. No one feature is diagnostic, consequently the whole clinical and radiographic signs of the case must be correlated before giving an opinion

The bone tumours of this nature respond to X radiation, and periodic radiographic examinations will show marked improvement in the appearance of the affected bone. So much so that some authorities regard this test as an indication of the nature of the tumour

W B Coley[1] claims that toxins of erysipelas and Bacillus prodigiosus bring about a similar healing of the tumour He published a radiograph showing almost complete decalcification of the upper third of the humeral shaft, and a further radiograph taken after an interval of 14 months, during which time toxins were administered, showing recalcification of the affected bone He states that the patient was well 6½ years after the treatment.



Fig 493. Radiograph showing structure of a pulsating tumour in the upper third of the tibia which responded to X-radiation. The abnormal pulsation ceased and all pain disappeared. The structure and clinical features suggested a hæmangioma.

It is the generally accepted opinion of authorities that, in spite of this apparent response of the tumour to X radiation, toxins, etc., metastases in other bones, the thorax, and brain, ultimately cause death.

Radiographs illustrating further examples of these tumours, with details of the clinical histories, are to be seen in the papers by *Coley Copeland* and *Geschickter Kirklin* and *Weber Kolodny Sevier* and *Sycamore* and *Holmes*

The pseudo-sarcoma in hæmophilia may present clinical and radiographic features which suggest sarcoma or Ewing's tumour

Hæmangio-endotheliomata of the bones produce a radiographic appearance which is characteristic. They are relatively uncommon and found in the bones of elderly patients The involved bones show a cyst-like expansion with well-defined septa (see Fig 418).

The tumours have been seen in the long bones of the extremities, the ribs, pelvis and vertebral column Though attention may be drawn to one bone only because of its marked expansion, further radiographs of the skeleton will usually show evidence of similar but smaller tumours, as in Fig 418

The radiographical definition of the bony septa indicates that the tumour is of slow growth. The tumour may pulsate and yield a bruit. Owing to the fact that the tumour may yield a bruit and that pulsation may be felt over it, it may be diagnosed as an aneurysm. This happened in the case of the patient whose radiograph is shown in Fig 418. Radiation to these tumours may cause resolution and disappearance of the

the sarcoma had been present for 9 months. The femur was amputated. Within 10 months the patient complained of pain in the chest and bloody sputum. Radiographs now showed multiple dense opacities in the lungs There was no sign of any local recurrence. The pulmonary lesions increased in size and number for some months Then the activity ceased and the lesions began to contract and become denser Radiographs of the chest twelve years after the amputation show multiple dense opacities. During the last ten years the patient has maintained weight and is now apparently fit. Apart from a sub-erythema dose of X rays one year after the amputation the patient had no therapy whatever The sputum has been examined on many occasions with negative results.

The radiographic appearances of ossifying hæmatomata in scurvy hæmophilia paralytic limbs, syringomyelia and tabes (see Figs 210 A, 494 495) syphilis (see Fig 117 A and other inflammatory lesions in bones (see Figs 496 and 498) in osteogenesis imperfecta (see Fig 470) and other obscure conditions (see Figs 483 A and B) should be considered in the diagnosis of sarcoma

The periosteal fibro-sarcoma, though producing marked swelling of the affected part, so that the skin is frequently stretched and glossy over it, may produce no change in the radiographic appearance of the bone Occasionally a thin line of periosteal new bone is shown at the site of the tumour an appearance which has led to the diagnosis of acute osteomyelitis being made, a diagnosis which is supported in some cases by an increase in the patient s temperature

If the radiologist sees the patient, the slight radiographic signs as compared with the very obvious tumour should warn him against such an error The details of the following case will illustrate the difficulties which may occur in the diagnosis of this type of tumour

P T., a youth of 22 years, received a blow on the thigh while on active service He was examined in hospital and a swelling of the thigh was discovered which was thought to be an abscess. An incision was made into it but no pus was found. The patient was sent to a base hospital where he was seen by a surgeon, who diagnosed the condition as aneurysm and requested the author to take a photograph of the limb in the theatre before the operation At the operation no aneurysm was found, but some yellowish necrotic tissue was found which was sent for histological and bacteriological examination. The section showed a mass of necrotic tissue and the bacteriologist reported the presence of *Bacillus Histolyticus* which when injected into a guinea pig produced what was described as the characteristic slough produced by this organism The tumour was incised in several places and irrigated with bactericidal fluids. It continued to grow and protruded through the incisions, which had failed to heal and gave the almost unmistakable signs of sarcoma but the bacteriological findings obscured the issue Radiographs at this stage showed a thin line of new periosteal bone formation running along the shaft in the thickest part of the tumour and this was interpreted as evidence of septic periostitis. Eventually the limb was amputated at the hip joint, and when sectioned showed the characteristic appearances of a periosteal sarcoma a diagnosis which was supported by the histological examination

The patient made a good recovery from the operation and after some weeks was transferred to another hospital.

After a few weeks an inquiry was received asking why this limb had been amputated, as the patient had shown marked improvement of his condition on anti-syphilitic treatment the suggestion being made that the lesion had been a gumma.

After the lapse of a fortnight a further communication was received to the effect that the patient had died and a post-mortem had revealed metastases of fibrosarcoma in the brain and heart.

As related, sarcomata are rarely known to follow bone trauma, and this may lead to difficulty in diagnosis

A patient, a girl aged 8 years, was referred to the author for diagnosis because a painful tumour of the ulna had been discovered by the doctor and on X ray examination the lesion

On the other hand, to regard the radiographic appearance of a lesion which has commenced in the diaphysis advanced through the epiphyseal cartilage and invaded the epiphysis, as evidence of a malignant growth, may result in unwarranted and grave surgical procedures.

There is no progressive bone lesion which shows less respect for the barrier action of the epiphyseal cartilage than tuberculosis. Therefore the possibility of such appearances being due to the tubercle bacillus should always be carefully considered before jumping to the conclusion that such invasion necessarily indicates malignancy.

Several members in one family may develop sarcomata. *C. H. Roberts* and *C. P.*



FIG. 493. Radiograph of ankle joint of paralysed limb showing disintegration of lower ends of tibial and fibular diaphyses with laminated periosteal secretion on the diaphyses and displacement of epiphyses. Inflammatory changes in a neurotrophic limb. Boy aged 8 years. Responded well to anti-syphilitic medication.



FIG. 496. Radiograph of large abscess in the lower third of the femur which had been affected with osteomyelitis for some years. The abscess cavity from which staphylococci were obtained is clearly defined but the covering periosteum shows no reaction. The upper part of the shaft is uniformly dense but not expanded.

Roberts reported cases of spontaneous and concurrent development in 3 members of one family—a brother and two sisters aged 23, 17 and 15 years. The humerus, tibia and femur were the bones affected.

A very remarkable case of osteogenic sarcoma has been published by *Kellogg Speed*. The patient, aged 21 had a tumour involving the lower half of the right femur. The radiographs suggested that it was an osteoblastic osteogenic sarcoma; this was supported by the clinical and histological appearances. There was an opacity in the left lung which was suspicious of a secondary metastasis. The history suggested that

bladder prostate thyroid, breast bronchus suprarenals kidney ovary uterus vagina, and other organs, very frequently occur in the bones Similar metastases may develop in melanotic sarcoma and from epithelioma (see Fig 407)

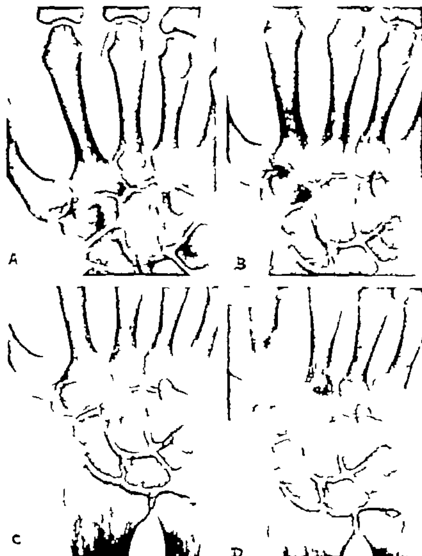


FIG. 407 Radiographs of A. W aged 60 years. Secondary epithelioma. The patient reported at hospital on April 29th 1947 complaining of severe pain at the back of the right hand and thumb with inability to grip. There was some swelling which was tender and felt of bony hardness. No glandular swelling was detected.

Radiograph A (29 4 47) shows normal bones and joints in the area

Radiograph B (2 7 47) shows some general osteoporosis with erosion of the adjacent surfaces of the trapezoid and os magnum such as is seen in early tuberculous arthritis.

Radiograph C (10 9 47) shows infiltrating erosion of the base of the second metacarpal bone the trapezoid, and os magnum associated with a severe degree of osteoporosis in all the other bones t the wrist—note the lower end of the radius, and absence of all signs of reaction.

Radiograph D (3 12 47) shows osteolytic erosion and destruction of the proximal half of the second metacarpal, the base of the third metacarpal, the trapezoid and the os magnum with a more severe degree of decalcification in all the bones of the wrist and hand.

The hand wa mputated but secondary lesions had developed in the region of the axilla and chest wall with a suspicious opacity at the lung base ? Primary

had been diagnosed as a sarcoma. The radiographs showed an irregular hazy deposit of calcium around the middle third of the ulnar shaft, *which almost obliterated the line of a fissure through* the bone. No history of any injury could be obtained, but the radiographic appearance suggested ossification in a periosteal hæmatoma. Further radiographs after an interval of a week confirmed this opinion.

The bones of a part with disturbed innervation (as in syringomyelia, spina bifida, etc.) may show much new bone as periosteal accretions and irregular ossified hæmatomata at the site of injury. It is gradually absorbed with rest. Such a reaction produced a *laminated exostosis from the lesser trochanter which was gradually absorbed.*

Bloodgood has published the radiographs and details of a similar case.

Periosteal fibro-sarcoma may show no periosteal new bone even when the tumour has assumed great proportions. The compact cortex of the bone in such cases frequently appears to be thicker than normal and the medulla correspondingly reduced, but the bone shows no evidence of osteoporosis or irregularity of contour. In the later stages a thin line of periosteal new bone may be seen along the shaft (see Figs. 66, A and B). *The absence of bone irregularity associated with a tumour of a limb of great dimensions* is indicative of a periosteal fibro-sarcoma. This tumour occurs more frequently during the age period 40–60 years, most commonly in the neighbourhood of the knee—the flexor aspect of the thigh and calf. The bones may be involved by pressure—periosteal reaction or local absorption; the tumour is usually confined to the soft tissues, fascia and muscular insertions. Usually single, encapsulated. Degeneration of contents with cyst formation or calcium deposition. Such a tumour is frequently associated with trauma, and a rise of temperature has led to the mistaken diagnosis of osteomyelitis, as in the case cited on p. 713, an opinion which is supported later by the radiographic appearance of periosteal reaction. Considered with the clinical findings, however, the radiographic appearances should not lead to any such confusion. It is essential in all cases where a malignant growth of bone is found that the lung fields should be radiographed for signs of metastases. In bone sarcomata these lung metastases may be found at the first radiographic investigation that revealed the primary growth, and may prevent a useless mutilation.

Primary periosteal sarcoma of a rib is not an uncommon tumour. Its development may be accompanied by a rise in temperature and local pain, and these, with the radiographic appearances, may lead one to the erroneous diagnosis of a small localised collection of fluid in the pleura (see Fig. 419).

Lymphosarcomata may produce marked destruction of the pelvis before the patient complains of pain in that area, and the radiographs may show that the whole or part of the pelvis has been transformed into bone containing irregular areas of condensation and large areas of "cystic degeneration" or erosion (see Fig. 323).

From the Registry of Bone Sarcoma, *Codman* shows that of 700 cases of bone sarcoma only 12 were alive after 5 years, and in 0 of these there was some doubt as to the diagnosis.

Usually sarcomata are single, but cases of multiple primary sarcomata have been described.

The discovery of a sarcoma in a young and apparently healthy person, and the dire painful progress of the tumour despite every means adopted to check it, is a catastrophe never to be forgotten by the observer.

Further illustrations and details of bone sarcoma are to be found in the papers by *Bloodgood, Codman, Coley, Kolodny, Phemister*[8] and the author.[26]

Carcinoma (see Figs. 48, F, 121, A and B, 230, A and B, 231, 321–327, 800, 411, 415, 430). Metastases from carcinoma of the stomach, œsophagus, bronchus, testicle

The periphery of a carcinomatous metastasis in a long bone may appear to exhibit cortical spicules It will be found in distinction to sarcoma that the spicules arise from a clearly defined site at which the compact bone has been destroyed also there is little soft tissue swelling

Metastases of carcinoma in bones may not become obvious for 20 or more years after removal of the primary carcinoma, and the patient may not connect the present malady and fail to give any history of the primary tumour

In searching for evidence of secondary bone metastases, stereoscopic radiographs are a distinct advantage Early metastases may be missed in the sacrum

Primary carcinoma arising from epithelialisation of chronic bone sinuses has been recorded.

Osteolytic areas due to secondary carcinoma sometimes show after 6—10 weeks of receiving 1 000 Roentgen units, deposition of calcium sufficient to make them denser than the adjacent bone Later the extra calcium is given up This phenomenon may also be seen after calcium medication or stilboestrol and after castration. At post mortem in one such case it was found that true healing had not taken place.

The changes in the skeleton due to Hyperparathyroidism or Myelomatosis may be mistaken for carcinomatosis.

Carcinomatous infiltration of bones may result in a uniform density which simulates the osteoplastic stage of Paget s disease It was seen by the author in a man aged 26 who had carcinoma of the stomach following 8 years of indigestion. Five separated vertebral bodies were of uniform density but unchanged in shape. He had a very high phosphatase figure. Histology showed infiltration of the affected bone with malignant cells. Metastases from malignant melanoma have been recorded as early as the first month of life. Such lesions may be symmetrical in distribution and the lesions may resemble the excavated extremities of the diaphyses in congenital syphilis The condition is rapidly fatal—even within one month of birth.

Neuroblastoma. This as its name implies is a tumour which arises from the parent neuroblast, either in the suprarenal or in some connection with the sympathetic nervous system. The suprarenal is therefore not involved in all cases It is a highly malignant tumour of young children, mostly under 5 years of age ; more common in the male It has been recorded in adults A familial tendency has been recorded by some authors When involving the suprarenal it may produce signs of dysfunction of this gland. Two types have been described (1) Pepper Type, (2) Hutchinson Type. The type described by *Pepper* is usually found in children under 2 years of age. It is predominantly an abdominal tumour and the liver is usually considerably enlarged by the infiltration and proliferation of malignant cells. No therapy is known to materially check its development and death results within a few months. Though there is evidence that metastases develop early the early death gives little time for their development. Massive retro-peritoneal and glandular tumours may be present.

The type described by *Hutchinson* is more common in the 2–7 years period. The nature of the disease may not be recognised for some months, the infant may be pallid and listless during this time and show a marked anaemia. Later the gradual development of exophthalmus on one or both sides with protrusion of the eye-ball and ulceration of the cornea occurs. Gradual expansion of the skull may be noted throughout a period of many months It is in this type, with its longer duration, that the metastases become prominent and marked radiographic changes can be detected in the skeleton. In some cases the metastases appear to spread on the side of the primary Radiographs in one case seen by the author revealed some calcification in the left suprarenal a large rounded tumour spreading out from the left mediastinum, erosion of the walls of the left orbit

It is important to realise that secondary carcinoma of bone may produce signs and symptoms which may be mistaken for the simpler lesions of arthritis, fibrositis, etc. The radiographs taken at the first examination may not show any abnormality or the slight changes may be missed for the early lesions of secondary carcinoma are not well defined indeed, they may not be recognisable until considerable destruction has resulted this may take several weeks or even months. The persistence of signs should call for repeated examinations. Unfortunately the long latent negative radiographic period is not appreciated as widely as it should be consequently when the report on *the first radiographs is negative, any request for a second examination is delayed,* frequently until a spontaneous fracture or other serious complication has developed. In the meantime painful and harmful manipulative procedures may have been carried out (see Latent Period, pp. 616–20 and Fig 497)

Once multiple carcinomatous deposits have been demonstrated in radiographs of the skeleton nothing can be done to help the patient by radiographic examinations of the alimentary canal, urinary tract, central nervous system, etc., in search of a primary secondary metastases in these structures cannot be distinguished from primaries in this way

The essential feature in radiography in suspected carcinoma of bone is to discover the lesion as soon as possible particularly if the signs and symptoms are such that manipulation may be attempted With our present poverty in agents which have any curative value the need for sparing the patient any painful procedure or any disturbing investigation must dominate our activities.

The radiographic demonstration of these metastases may be the first indication of the presence of any malignant tumour in the patient. It is not uncommon for the radiologist to discover areas of bone destruction indicating such metastases when carrying out X-ray investigations of patients complaining of pain in the back or "sciatica. Other cases are revealed on X-ray examination for fractures In a number of cases of suspected malignant disease in which no localising signs or symptoms could be detected the author has been able to indicate secondary metastases in the bones of the pelvis or in the lungs.

The primary carcinoma may not be found until several months have elapsed after the bony metastases were discovered by the radiologist, or may not even be discovered until a post-mortem examination is made. This fact may give rise to the opinion that the bony lesion shown is the primary tumour A further radiographic examination of the lumbar spine, pelvis and upper thirds of the femora often reveal other lesions.

The radiographic appearances of bone metastases of carcinoma have been described and illustrated in the chapters dealing with the spine and pelvis

Further illustrations and details are to be found in the papers by *Hart* and *Duval*, *Ginsburg*[1] *Simpson* (thyroid metastases), *Dresser*[1] (hypernephroma), *Woolstein* (neuroblastoma) *Leddy* (breast) *Copeland Joll*, *Weinberg* (general bone metastases)

The presence of isolated bone metastases may be first indicated by a spontaneous fracture or by a radiographic examination undertaken to ascertain the cause of pain.

Though such metastases are frequently the cause of complete invalidism for the remainder of the patient's life it should be realised that remarkable resolution of these metastatic bone lesions and relief from pain permitting a return to normal life at any rate for a period has followed within a few weeks castration, oöphorectomy or the administration of stilboestrol or X radiation therapy

In this way X radiation performs one of its most beneficial results. Radiographs, illustrating the beneficial effects of X radiation on bone metastases, are published in the papers by *Herendeen Leddy Pfahler*[1] *Rose*[2] and *Wood*

leukaemia with some apparent increased density of the shaft, it may appear to be laminated as in Ewing's sarcoma or so expansive as to suggest an ossifying subperiosteal haematoma, or it may show a fine palisade spicular appearance. These periosteal changes indicate the comparative chronicity of this type. Areas of osteolysis may develop and spontaneous fracture may occur. In some cases the lesions which develop show characters of both types. It has been suggested that the Pepper type arises from a primary in the right suprarenal while the Hutchinson type arises from the left suprarenal and anatomical differences in lymphatic distribution have been accredited with the cause of the types, but investigation of the cases published do not confirm this theory. Neither type shows effective response to therapy.

SUMMARY OF EVIDENCE ON BONE TUMOUR

From a study of all the features of the cases he has examined in the light of our present knowledge the following represent the author's conclusions —

(1) The most important decision to make in the diagnosis of a bone tumour is whether the lesion is simple or malignant. In most cases radiography affords the earliest and most useful information for this purpose without disturbing the patient or the lesion.

(2) Few patients are presented for radiographic examination in the very early stages of malignant disease, for they appear to be in good health and apparently the clinical signs do not suggest to the clinician a lesion serious enough to warrant an X ray examination.

(3) Different lesions which present histological characters indistinguishable from one another may present totally different clinical and radiographic features: one may indicate simplicity, another malignancy. Though different lesions may present the same radiographic characters at one stage, serial radiographs at intervals will indicate wide differences between simplicity and malignancy.

(4) Simple tumours of bone present characteristic radiographic appearances which permit of their identification by the experienced observer.

(5) Malignant tumours of bone in the early stages present variable but characteristic radiographic features (see Figs 485 and 486).

(6) The recognition of these typical features should be followed by an X ray examination of the lungs and pelvis for the demonstration of possible metastases. The possibility that the bone lesion may be a metastasis from a primary carcinoma elsewhere should be considered.

(7) No treatment should be administered until a complete radiographic record has been made. X radiation when first applied tends to obliterate the evidence of malignancy in some cases.

(8) When it has been established by clinical and serial radiography that the lesion is malignant and apparently operable, amputation should be performed as early as possible—it provides the best chance of cure we yet know. A prior biopsy merely to obtain histologic material would not help because it would accelerate the development of the local growth even if not the dissemination of metastases and provide material the histological appearances of which may be misleading. Further, it would damage the scaffolding on which any repair would be based. There are indications that X radiation therapy administered prior to surgical removal increases the possibility of cure (see Clause 7). In a few cases X-radiation therapy destroys the malignant cells and the lesion consolidates (see Figs 489 A and B). Though with our present imperfect knowledge we regard prompt amputation (with perhaps prior X radiation) as the only

and irregular decalcification of the left side of the pelvis. Later a more general distribution was seen. The complete radiographic picture is typical. The most marked feature in the skull is diastasis of the sutures—usually the coronal suture shows the most expansion (see Fig 448). Areas of decalcification as in carcinomatosis may be seen. Where there is a soft tissue tumour of the scalp spicules may be detected growing into it from the outer table. Erosion of the deeper walls of one or both orbits may be present. The chest may show one or more rounded apparently encapsuled tumours growing from the mid-line. The abdomen may show some calcification or enlargement of one or both suprarenal glands. The pelvis may show irregular decalcification often more marked on one side than the other sometimes with spicular growth on the periosteal borders.

The long bones, including the phalanges, show periosteal reaction suggesting subperiosteal infiltration. This may be present along the whole shaft or in part. It may take the form of a regular periosteal accretion as in periostitis and some cases of

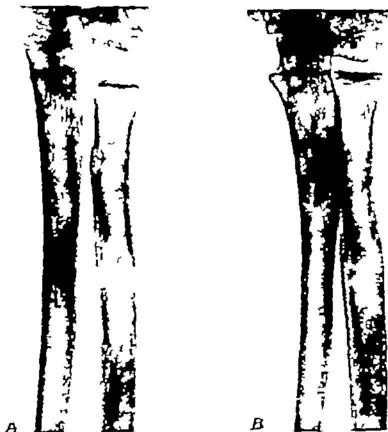


FIG. 498. Radiographs of forearm of boy H. P aged 13 years. Patient had received a blow on the forearm September 23rd, 1947. He began to have pai early in October.

The radiograph A, November 4th, 1947 shows an ill-defined area of osteolysis in the region of the nutrient foramen of the radius and an ill-defined periosteal reaction along its shaft. The diagnosis of Ewing' sarcoma wa put forward. The author was consulted and advised that the lesion was inflammatory and suggested immobilisation in plaster a blood test for the Wassermann reaction, anti-pyogenic medication and no biopsy. The Wassermann reaction wa negativ. There were 3 000 white blood cells of which 47 3 per cent were polymorphs, 7-3 per cent were eosinophil and 45 per cent were lymphocytes.

The radiograph B, January 1st 1948 shows resolution following immobilisation.

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